Aalto University
School of Engineering

Emma Unonius

MID-TERM CAPACITY PLANNING PROCESS AND TOOL FOR TEXTILE SERVICES COMPANY

Thesis submitted for examination for the degree of Master of Science in Technology.

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Thesis supervisor: Professor Esko Niemi
Thesis instructor: M.Sc. Johanna Bilund

Aalto University
School of Engineering

Aalto University, P.O. BOX 11000, 00076 AALTO
www.aalto.fi

Abstract of master's thesis

Tekijä Emma Unonius		
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Tiivistelmä

Tämä yrityksen työvaatepalveluiden kehitysprojekti toteutettiin Lindström Oy:lle. Projektin tarkoitus oli tehdä tarvekartoitus keskipitkän aikavälin hankinnansuunnittelulle, sekä kehittää sille prosessi. Tarkoitus oli myös kartoittaa vaihtoehtoja uuteen prosessiin tarvittavalle ohjelmistolle. Prosessin tulee sitoa pitkän aikavälin suunnitelma hankintaprosessiin. Tämä tehdään käyttämällä pitkän aikavälin ennustetta pohjana, mutta suunnitelmaa päivitetään useammin, viikoittain. Suunnitelman päivittää sekä validoi Midterm Planner -henkilö. Vain hän tekee muutoksia suunnitelmaan. Kun suunnitelma on tehty, se jaetaan toimeenpaneville tahoille.

Työkalun etsiminen aloitettiin Lindströmillä heidän käytössään olevista järjestelmistä. Näitä järjestelmiä käytetään eri osissa hankintaa sekä hankinnan suunnittelua. Kaikki järjestelmät ovat hyvin erilaisia ja kaikkien vahvuudet sekä heikkoudet ovat erilaisia. Mikään järjestelmistä ei myöskään täyttänyt kaikkia työkalulle laadittuja vaatimuksia. Tämän projektin lopputuloksena ei yhtä ilmiselvää kohdetta löytynyt, mutta selkeä suosikki kylläkin.

Avainsanat Kapasiteettisuunnittelu, aikataulutus, tarvekartoitus, määrittely, prosessin kehitys,

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Author Emma Unonius		
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Abstract

This development project was carried out for Lindström Oy. The purpose of the project was to do a needs assessment for medium term purchase planning and develop a process for it. The goal also included comparing alternative software as a tool for the process. The process needs to bind the long term plan forecast to the ongoing purchasing process. This will be done by using the plan as a base and updating the plan more often, in a weekly basis. The plan is updated and validated by the Mid-term Planner who is the only one making changes to the plan. The plan is then shared with the execution parties.

The search for the application software was started from what are already in use at Lindström. These software are used in different levels of the purchasing and production planning. All systems are very different and all of them have very different strengths and weaknesses. None of the solutions were a perfect match and were unable to fulfill all the requirements set for the tool. There was not one clear winner, but one favorite was found.

Keywords Capacity planning, scheduling, needs assessment, specification, process development

Foreword.

I would like to thank Lindström Oy for this great opportunity to show and use everything I have learned in my studies. This subject for thesis was really a dream come true: a real project that combines production planning and an IT project. The fact that the process was started for a true need for a solution, made the subject twice as interesting. Planning and scheduling is something that I have interest in and this combined to a system purchasing project was educational.

I would like to thank my advisor Johanna Bilund for the guidance. An acknowledgement to the whole steering group of the project for making the project move to the right and feasible solution with Ismo Nastamo, Taina Sihto, Risto-Pekka Rantanen and Tuija Mäkitalo. A special gratitude to my supervisor Taina Sihto who considered me to be suitable for this project and really impacted my career by hiring me a year ago. Also I received a lot of support from other people in the company by kindly sharing their knowledge. During this project I was in contact with multiple service providers for IT systems and I would similarly like to thank these people for treating me kindly in my first time in a situation like this.

My supervisor professor Esko Niemi has offered me academic counselling and support in my journey towards graduation. He has shown patience and consistency in his recommendations.

At the end I would like to thank my friends and family for supporting me in this part of my life when I needed the support. Especially the peer support from fellow students and my friends helping me with the qualities I am not good in.

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Emma Unonius

Emma Unonius

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Notation

D_{ijl}	Demand for product
TC_j	Tardiness penalty per unit per week of product *j* that arrive late at the customer
TD_j	Tardiness penalty per unit per week of product *j* that arrive late at the DC
TT	Penalty for never delivering one unit of product
cp_{jk}	unit cost of producing part
cs	unit storage cost in DC of any product type
$c\tau 1_k$	unit cost of transportation from factory *k* to DC
$c\tau 2_k$	unit cost of transportation from factory *k* to the customer
$c\tau 3$	unit cost of transportation from DC to the customer
I	week
J	product
k	factory
l	level
tp_{jk}	time
$t\tau$	transportation time between any two levels is assumed to be one week
x_{ijk}	number of units of product *j* produced at plant *k* during period *i*
y_{ijk2}	number of units of product *j* transported from plan *k* to the DC in week *i*
y_{ijk3}	number of units of product *j* transported from plant *k* to customer in week
z_{ij}	number of units of product *j* transported from the DC to the customer in a week *i*
q_{0j2}	number of units of product *j* in storage at the DC at time 0
q_{ij2}	number of units of product *j* in storage at the DC at week *i*
v_{ij2}	number of units of family *j* that are tardy, meaning have not yet arrived, at the DC in week *i*
v_{4j2}	number of units of product *j* that have not been delivered to the DC by the end of the planning horizon
v_{0j3}	number of units of product *j* that are tardy at the customer at time 0
v_{ij3}	number of units of product *j* that are tardy at customer in week *i*
v_{4j3}	number of units of product *j* that have not been delivered to the customer by the end of the planning horizon

Abbreviations

APS	Advanced Production Scheduling
BOL	Bill of Labour
BOM	Bill of Material
BUB	Business Unit Buyer
BUM	Business Unit Manager
CIF	Customer Information Form
CMT	Cutting, Manufacturing and Trims
CPO	Chief Purchasing Officer
CRM	Customer Relationship Management
CRP	Capacity Requirements Planning
DC	Distribution Centre
DP	Quintiq Demand Planner
D365	Microsoft Dynamics 365
EDD	Earliest Due Date
ERP	Enterprise Resource Planning
eS&OP	Executive Sales and Operations Planning
FCFS	First come First served
FIFO	First-in First-out
FP	Full Package
GCM	Global Category Manager
HOP	Head of Procurement
KPI	Key Performance Indicator
LIFO	Last-in First-out
LMM	Lindström Management Model
LOT	Longest Operation Time
MES	Manufacturing Execution System
MOM	Manufacturing Operations Management
MP	Quintiq Macro Planner
MPS	Master Production Schedule
MRP	Material Requirements Planning
MRP II	Manufacturing Resource Planning
MTO	Make-to-order
MTS	Make-to-stock
OEM	Original Equipment Manufacturer
OPP	Order Penetration Point
PLM	Product Lifecycle Management
RCCP	Rough-cut Capacity Planning
RFI	Request for Information
RFP	Request for Proposal
SME	Small and Medium-sized Enterprises
SOT	Shortest Operation Time
S&OP	Sales and Operations Planning
S&PP	Stock and Procurement Planning
WIP	Work in Progress

1 Introduction

Capacity planning is a process where capacity needed meets its demand. This is a process that depends on many factors, such as the area of business and seasonal changes in demand. By having more accurate plan, less capital is tied in stock, the operating reliability increases and customer satisfaction improves. Accurate plans decrease the difference between forecasts and actual purchase orders. There are constricting factors such as resource capacities and raw material stocks that can be considered as limitations to capacity planning.

Problems typically occur when the demand varies and there is not enough supply to react to the changes. One solution for this problem is to keep large inventories but these always tie up capital and are inefficient. Another way would be to keep manufacturing close to the customer and react to customer orders fast, but this is usually very expensive or even impossible to maintain. The optimal solution is settling somewhere between these two examples. This can be done by optimizing safety stocks and having different kinds of suppliers with different lead times.

There are different levels of planning commonly used. The planning is done on different levels of the company, from administration level to the manufacturing level. This presents different time horizons and levels of aggregation. On high level there is no need for detailed information of production. In the same way there is no need for aggregate level forecasts on shop floor.

Lindström Oy operates in 24 different countries with the main business area in renting workwear. The garments are acquired from different vendors and from one own factory located in Latvia. Development of procurement planning has started in workwear services which has the most challenging supply chain. Main target for Lindström Oy is to

"Create value for the customer in everything we do."

Functional and efficient supply chain is a way to increased customer satisfaction. To get to this target, good planning is needed to handle the change from forecasts to customer orders.

Lindström purchases most of its products from different suppliers. Instead of planning production, procurement is planned. The procurement as a term describes all those processes concerned with developing and implementing strategies. This is done by managing the overall goals and to maximising the value released by minimising the total cost of ownership.

There are many terms that are involved with the purchasing of a good. Purchasing is focused on the tactical acquisition of goods and services and the execution of plans more than the development of strategies. The procurement process addresses all pre-contract and post-contract processes. Supplier relationship management, performance management and supplier development are the procurement activities that apprehend the potential value created during the sourcing phase.

Purchasing describes all those transactional processes concerned with acquiring goods and services, including payment of invoices. It is a narrower term than procurement, describing

reactive, tactical processes. The purchasing process differs from sourcing or procurement in three key aspects: the scope of the process, the degree of influence exerted on the process, and the nature of the choices made. In terms of scope, the purchasing process typically begins after a user has selected the solution or defined the need, and ends on the receipt of the good or service and payment of the supplier's account.

Sourcing describes all those activities within the procurement process concerned with identifying and evaluating potential suppliers, engaging with selected suppliers and selecting the best value supplier. The outcome of the sourcing process is usually a contract or arrangement that defines what is to be procured, on what terms and from which suppliers. The scope of the sourcing process typically includes the following key activities: understanding the need; evaluating the supply market; developing an appropriate strategy and executing that strategy.

Currently Lindström Oy uses many different software in the supply planning process. Significant changes in these systems are on-going and there is a need to document and update the process. As part of this process, development of the mid-term capacity planning process is required. There is no functioning tool or process for mid-term capacity planning. Main focus in this project will be mid-term planning for workwear.

At the moment there is a system that is used for long-term planning with a planning horizon from one month to 16 months. This plan shows the big picture of the production and purchase plan. There is also a tool used for short term customer projects planning and a system for executing the procurement.

Lindström has three types of orders in the scope of supply planning: customer specific orders, replacement orders and additional orders. Projects are either new customer orders or change of garments in case of re-design that require special attention and scheduling. Replacement and additional orders are the demand caused by maintaining existing customer inventory and are regularly purchased as they come. In this case the forecast of this type of demand should be considered quite stable and accurate enough.

The problems detected are caused by difference in the actual demand and the forecasts. One main factor causing difference are the customer projects which affect the long-term plans making them non-optimal. This means that manufacturing capacities can be consumed before the actual previously planned orders are placed, making the long-term forecasts unfeasible. Also peaks in the maintenance demand cause variation and since the long term plan uses historical data when forecasting small additional orders and replacement orders, unexpected peaks in the demand can set the plan wrong. The aggregate planning levels the plans so that the natural variation is evened out.

The difficulty in the purchase planning is caused by fabrics. It is not possible to just direct certain orders from one supplier to another even if both of the suppliers are listed as alternative suppliers for a product. The garment manufacturers must have the material used for the garment in stock in that given time or the manufacturing is not possible.

This project is started to find solutions for the difficulties mentioned earlier and to determine the tools and processes to improve the efficiency and availability in the supply chain. The objective of this thesis is to develop and describe a process that solves the issues and analyse

alternative tools for the procedure. This process has two main focuses: capacity tracking and project scheduling. In capacity planning, it is important to know the current situation with knowledge of the occurrences in the past and the plans for the future. Many times if the capacity of a supplier is overbooked, some of the orders move to the next week. There could be a reason to make some permanent changes to the situations, if this is happening for a supplier continuously. The current situation sets the plan for procurement and the future scenario is used for planning. There is a special need for scheduling customer projects meaning a display of suitable suppliers for new products and important dates like due dates for fitting information.

2 Lindström Oy

Lindström Oy is one of Europe's leading textile companies. It is a family business with exactly 170 years of experience in the field. Lindström offers solutions for cleanliness and interior design of facilities, corporate clothing and protection. The subsidiary Comforta offers textile services to hotels and health care practices. The turnover of Lindström Oy is 323 million euros, with personnel around 3500. The company offers services in 24 countries in 80 different operating locations. These countries are shown in the Figure 1 below. (Lindström, 2017b)

Lindström offers workwear services in all of its countries of operation and mat services in over 10 countries in Europe. Addition to this, its service selection includes personal protective equipment, shop towel, hygiene and restaurant textile services as well as the textiles for hotels and the health care industry. The company offering these services, Comforta, operates only in Finland, Sweden, Estonia and in St. Petersburg in Russia. (Lindström, 2017b)

Figure 1 Lindström countries (Lindström, 2017a)

2.1 Workwear

The business of textile services focuses on workwear. They offer a rental service in which the customer does not have to think about the maintaining and purchasing of garments to employees. This way they do not have to hire someone to take care of them. The service increases flexibility on workwear because there is no longer need to worry about having all the sizes and types in stock, Lindström does it for the customer. It is also safer when employees get suitable workwear that are proper for the job. There is no need to worry about the design but only select the design wanted.

The service includes having clean and maintained workwear always available by delivering the garments on weekly basis. The volume of workwear should be calculated so that there

will not be shortage. The customer saves money, since they do not tie up capital nor personnel resources to acquisition, maintenance or storage of the workwear. Because it is a service, there are no different collections used simultaneously. The whole collection is unified and matching the company brand. The customer does not have to worry about the changing legislation, because Lindström monitors it and different standards and new operating models in varying fields to reassure safety at work. The service is an agile and ongoing process. A needs assessment is done, where the collection is planned and products are fitted. Then the procurement of the garments is done. The garments will be washed and maintained by Lindström laundries. The garments are stored, repaired and renewed by the laundry if necessary. The clean and repaired workwear is delivered on weekly basis to each employee's locker or another predetermined place. Lindström also takes case of the disposal of used garments ecologically. (Lindström, 2017a, 2017c)

In Lindströms workwear services the uniforms feature RFID chips. These chips are used to collect data on the clothes in order to optimise the customer and user experience. The garments are allocated to appropriate applications, as work uniforms or for other purposes, based on their condition. This is handled over the total life cycle of the garments. Lindström, as the owner of the pieces, has an interest in maintaining the garments in good condition to ensure a long useful life for them. (Sitra, 2017)

A typical contract term for a customer is three years. During this time Lindström has the opportunities for cross-selling other services, such as mats and personal protective equipment. This business model supports high levels of customer retention and satisfaction. Management becomes easier with a joined-up operating model and streamlined costs. (Sitra, 2017)

Because the products are mass customized, there is a large variety of them. There are around 4500 products in workwear alone that come from over a hundred vendors. Not all vendors make all products and the level of customisation varies. Workwear is an important part of work safety. The garments have to pass product standards and also keep the high standard in circulation. The requirement for the fabrics used and the manufacturing of workwear differ between different industries. For example the requirements for garments used in clean room alter greatly from a welders uniform. Figure 2 shows a typical Bill of Material (BOM) in Lindström products. There are 18 different components that are used to make one garment. Some of the materials needed are pure estimations, for example how much sewing thread one garment will take.

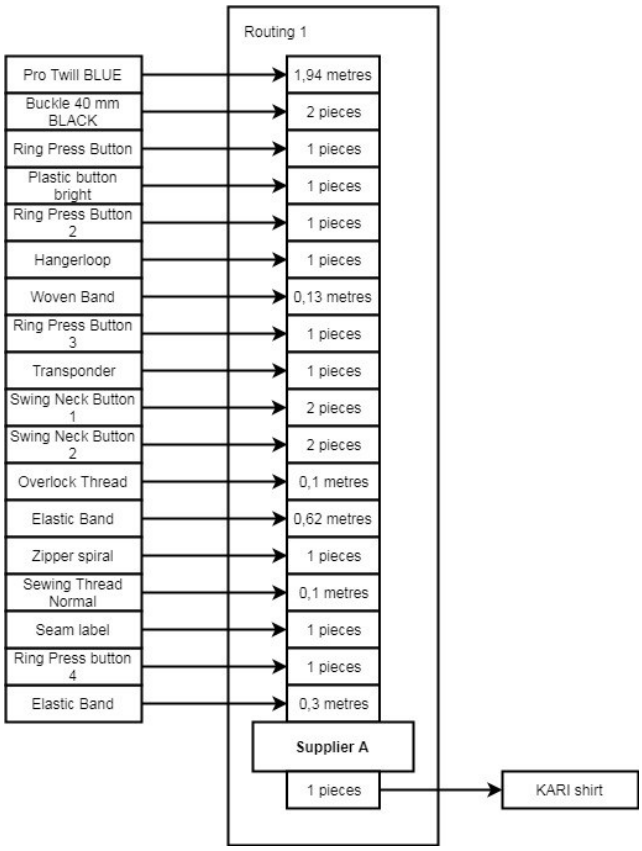

Figure 2 Example of a BOM for a Lindström product

Product development department designs product platforms. These platforms are parts of product groups, such as pants or jackets. The platform defines the model and fit for the garment with variety of elective features such as different pockets and sleeve lengths. The platform also lists elective materials and colours that can be used in the product. In workwear there are around 200 different platforms in use. Products are constructed from these options. Every product built has a product code, planned collection, concept, BOMs and alternative supplier assigned to produce the garments. Each supplier has produced a sample of the garment. (Jokinen, T., 2018)

The product repertoire varies also geographically. The sections are: China, India and Europe. Because of the differences in the shapes and sizes of people in these different market areas, the product models offered are not the same. Also all the Lindström countries have their own country specific collection that is sold primarily in the country. This collection has the prices already contracted. This is done to ease the selection for the customer. (Jokinen, T., 2018)

3 Capacity planning

The process of planning and scheduling has started from simple gathering of materials and developed into highly advanced online optimized scheduling. This chapter is about the evolution of capacity planning and its process. Capacity management is about providing sufficient capability to satisfy demand at the right time. It is sometimes referred as aggregate planning because of its level of observation.

Planning altogether is done on different levels in the company. The level of detail and time horizon often depends on what level in the company the plan is used. On higher level, plans with less detail and longer time horizons are ideal. If the plan has all the details in it, the plan as a whole can get blurred. Then in customer interface it is important to know the details.

3.1 Capacity Requirements Planning

Capacity Requirements planning handles different situations. If the plan shows complications, many steps can be taken that correct them. Most of these steps concern workforce, work could be done in another shift, more people could be hired, overtime could be reserved or personnel or work be moved to another unit. In some situations, the work could be subcontracted, moved to another facility or rescheduled. (Ptak, C.A., Smith, C., 2011)

The objective of capacity management is of course to improve performance. It does this by improving quality of service and products by reacting to capacity fluctuations. It can speed up the response to customer by improving production flow. The dependability of supply improves because of the levelled production that minimizes the use of maximum capacity. The flexibility of volume will be enhanced by surplus capacity that allows to respond to unexpected increase in demand. Costs are balanced when the demand meets the capacity without extra or underutilization. No revenue will be lost because of satisfied demand but working capital is affected by possible build-up products. (Slack, et al, 2011,p. 170)

In its simplicity capacity management contains three steps:

1. Measure aggregate demand and capacity
2. Identify the alternative capacity plans
3. Choose the most appropriate capacity plan

The demand and capacity need to be measured in a very collective manner. This could mean that the demand nor the capacity is yet to be promised to a certain product or a customer but in an overall estimation. The next step is to create alternative solutions on how to use the capacity. For example most of the demand could be directed to overseas production and sudden peaks on the demand are produced by the production facility near the customer. Another plan would be manufacturing only a portion of the demand overseas and the rest nearby. The most appropriate plan is selected depending on the situation. (Slack, N., Brandon-Jones, A., Johnston, R., 2011,p. 170)

Slack, Brandon-Jones and Johnson list three alternative methods for capacity planning to respond to fluctuations of demand: Level capacity plan, Chase demand plan and Demand

management. Level capacity plan does not consider demand fluctuations and keeps the capacity constant. This may increase process utilization and productivity with low unit costs. It may also create excess inventory. This method is best used when the demand is certain.

With the chase demand plan the capacity is racing the demand. It is used when demand varies a lot or the storage of the product is difficult. The methods used for adjusting the capacity are by adjusting productive hours and managing human resources. This type of capacity management demands more sophisticated planning, meaning forecasts and advanced scheduling.

The last method is demand management. In this method the demand is affected, for example through price or availability. This way the demand can meet with the supply. This can be done for example by offerings and floating prices. If there is plenty of overstock, a sale will most likely increase the pace of sales. (Slack, et al. 2011,p. 178)

3.2 Production control strategies

There are many strategies used for production planning and control. These strategies are often categorized as push- or pull-type. One way to distinguish the strategy used, is to study how the work is triggered. In a push system the work orders are scheduled by a central system based on actual or forecasted demand, when in a pull system, the work is authorized based on the current system status. Push systems can proactively operate based on forecast when pull systems only reach to the actual status of the system.

The pull in a pull system comes from the fact that the work-in-process (WIP) is limited between process steps. Because of this, the preceding process can only produce if there is sufficient space available in the buffer to the next process. Pull is also used to describe a replenishment system where different variants of products are stored to fulfil the customer demand. A new product is only re-produced when a variant is removed from the stock.

A third concept is a concept of internal production logistics where production line is supplied with raw materials based on actual demand. Most systems in real life are not clearly push or pull, but something in between. One way to measure the level is the order penetration point. (Karrer, 2012, p. 9)

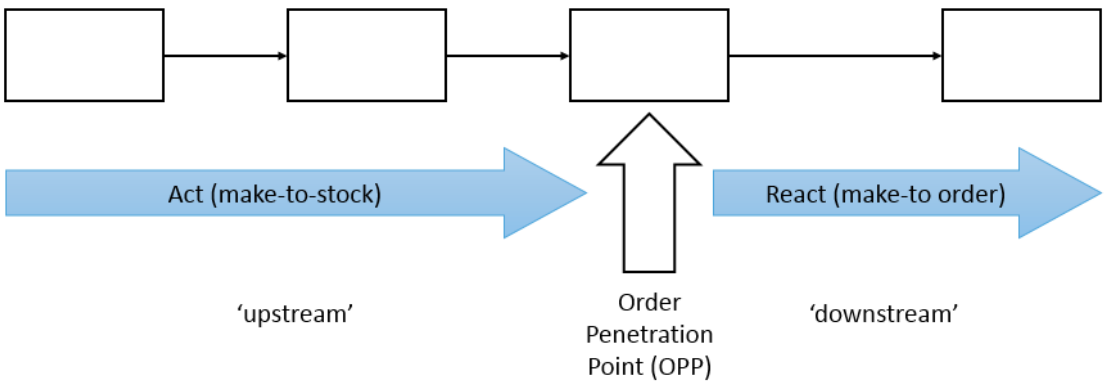

Figure 3 The order penetration point (Karrer, 2012, p. 12)

Order penetration point (OPP) is sometimes also called customer decoupling point, is the point where the customer order enters the system. It defines the stage in the manufacturing value chain, where a certain product is linked to a specific customer order.

In Figure 3 above the OPP divides the manufacturing to upstream and downstream. These parts use different production strategies. Upstream the products are make-to-stock or made to forecast. The8 production is done based on a forecast or other push strategy. After the OPP, down-stream of the production the manufacturing reacts to customer orders. After this stage, a pull strategy is used. Before the OPP there is still uncertainty in the demand and a way to deal with it is needed. After the OPP the demand is certain so there is no need to keep excess inventory, in this point of view the OPPs optimal position is as upstream as possible. However this will affect the lead time to the customer and the customers do not like to wait. This way the determination of OPP location is a strategic decision. (Karrer, 2012, p, 12)

3.3 Evolution of manufacturing planning

There are many different tools that have been used to plan manufacturing. Still the concepts and tools used for production planning have rotated around the same topics. The evolutions from material requirements planning to web-integrated enterprise resource planning can be seen in Figure 4 The development of ERP (Slack et al. 2011, p. 242).

In early 1960s Joseph Orlicky and others developed Materials requirements planning (MRP) to exploit computers for scheduling and inventory control. The main focus of MRP is on scheduling jobs and purchase orders to satisfy material requirements generated by external demand. It works backwards from production schedule to derive schedules for components. As a push system, MRP schedules what should be produced based on the demand. (Hopp, 2001, s.109)

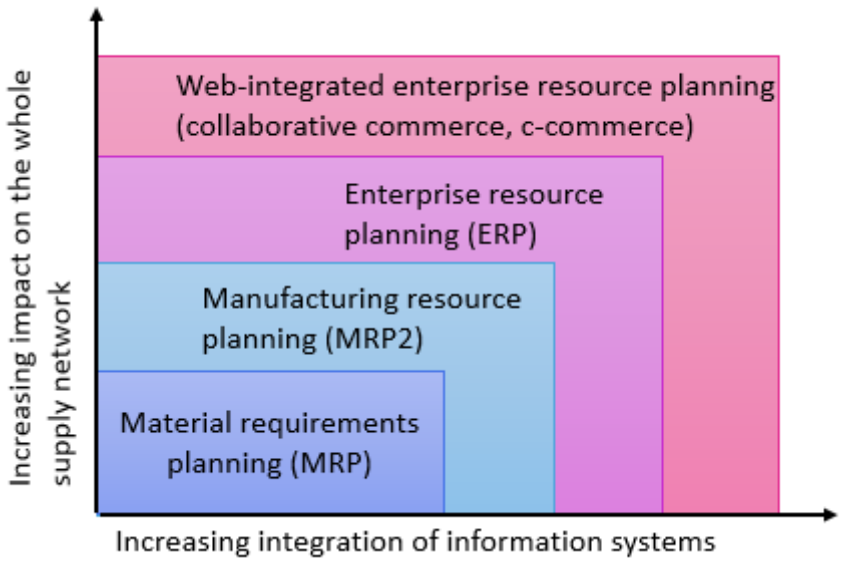

Figure 4 The development of ERP (Slack et al. 2011, p. 242)

Manufacturing resource planning, MRP II is the next version of MRP. It adds more functions to the regular MRP, such as demand management, forecasting, master production scheduling and capacity requirements planning. This increases its control to the whole supply network. (Hopp, 2001, s.135)

Enterprise resource planning, (ERP) is the next form of MRP. It includes all operations of the enterprise, including manufacturing, distribution, accounting, financing and personnel. In Figure 4 the last phase is web-integrated ERP system that has even more integration with information systems and a greater impact in the supply network as a whole. (Hopp, 2001, s. 143)

These ensembles include different modules that are used in the planning. These modules all have their meaning in the system and bring more information to it. Master production schedule (MPS) contains gross requirements, the current inventory status known as on-hand inventory, and the status of outstanding orders both purchased and manufacturing known as scheduled receipts.

Capacity Requirements Planning (CRP), that is included in the MRP II, generally involves infinite capacity planning meaning that there are no constraints concerned. The module only calculates the capacity needed for production and does not compare it to any restrictions. This helps to determine the amount of capacity needed to fulfil the demand. (Hopp, 2001, s. 139)

The next generation focuses more in the shop floor production planning and control. Manufacturing execution system (MES) is an automated implementation of what MRP II called shop floor control. MES tracks work in process automatically, records process, yield, and quality data and executes a schedule by releases of new jobs into the system. It is debated whether MES is already part of ERP systems or an independent entity. (Hopp, 2001, s. 145)

Manufacturing operations management (MOM) activities are activities of a production facility that coordinate the personnel, equipment, material and energy in the conversion of raw materials and parts into products. It includes activities of managing information about the schedules, use, capability, definition, history and status of all the resources within and associated with the manufacturing facility. (ISA-95)

There is also an update to the capacity planning used. The more modern scheduling systems use so called finite capacity scheduling. ISA-95 defines it as: “a scheduling methodology in which work is scheduled for production resources, such that no production resource capacity requirement exceeds the capacity available to the production resource.” Unlike in infinite capacity planning, it takes constraints and limitations into account. (ISA-95)

Advanced production scheduling (APS) is used to analyse the data up and down in the organisation. The capabilities of APS are as varied as the vendors supplying the system but most APS applications are memory-based algorithms that perform functions. These include finite capacity scheduling, forecasting, available to promise, demand management, warehouse management, distribution and traffic management, etc. In many cases, ERP vendors partner with more specialized software developers to provide these functions. (Hopp, 2001, s. 145)

3.4 Manufacturing planning

In Figure 5 the manufacturing resource planning is divided into three phases: Long-range planning, Intermediate-range planning and Short-term control.

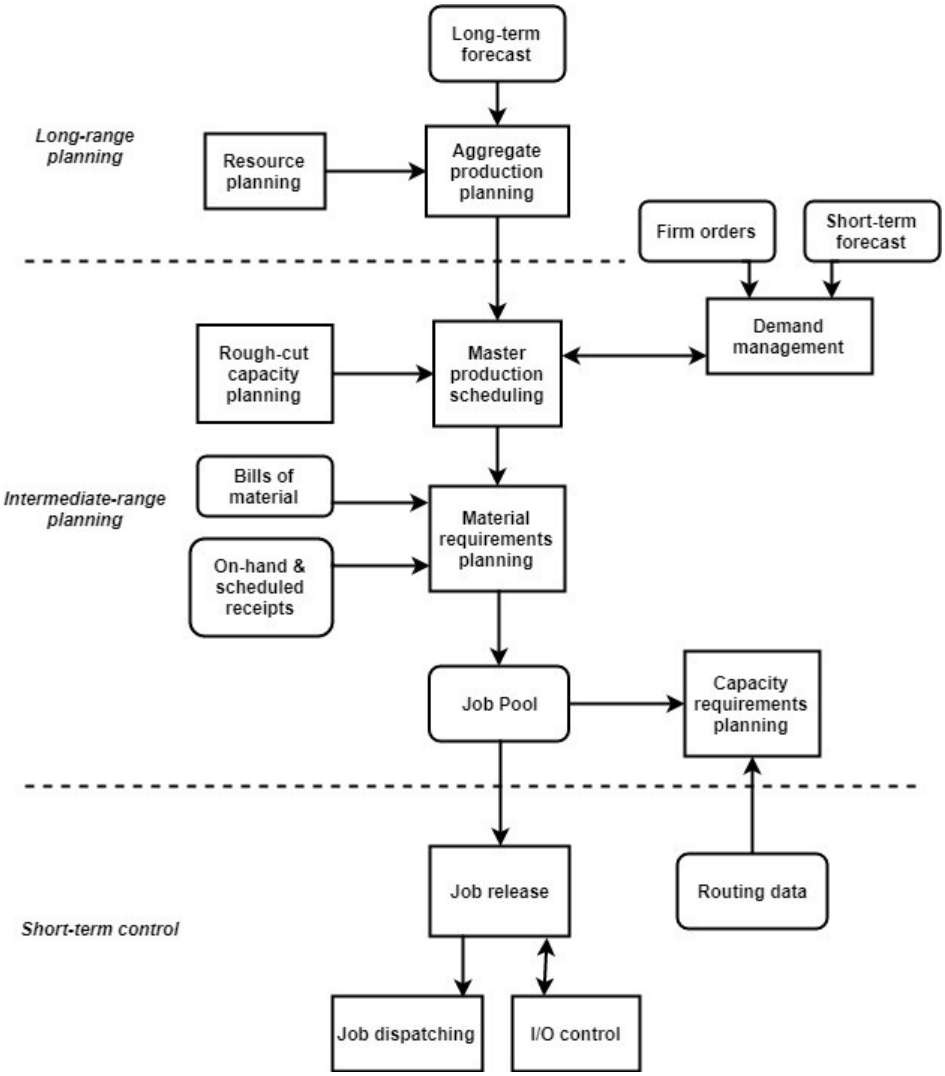

Figure 5 Manufacturing resource planning (Hopp, W. J., Spearman, M. L., 2011)

Long term planning has three functions: resource planning, aggregate planning and forecasting. The range of this planning phase varies from months to years. The plan is run from once a month to once a year. The plan is not very detailed, mostly including product families and groups. Long term forecasts are used to determine the capacity, tooling and personnel requirements. These forecasts are late converted into short term forecasts with more details. Capacity requirements are determined in resource planning function over long term. The information output about the available capacity is used as a parameter in aggregate planning function. Aggregate planning determines the levels of production, staffing and inventory in

long term. The level of detail is typically one month and for part families. Many times optimization methods such as linear programming are used to assist the planning process. (Hopp, W. J., Spearman, M. L. 2011)

Intermediate-range planning includes demand management, rough cut capacity planning, master production scheduling, material requirements planning and capacity requirements planning. In this level the long term aggregate plan is converted into more detailed forecast and individual customer orders are included with demand manager. The output of demand management is a mixture of set customer orders and forecasts of actual orders. It is done by using technique available-to-promise which tells the planners which orders on the Master Production Schedule (MPS) are committed to a certain customer order and which are available to for new orders. MPS takes the demand forecast with the firm orders from the demand management module and generates an estimated schedule at the highest level of planning detail by using aggregate capacity limits.

Rough-cut capacity planning (RCCP) is used to check capacity of a few critical resources to ensure the feasibility of the MPS. Although more detailed than aggregate planning, RCCP is less detailed than the capacity requirements planning (CRP). CRP is another tool for performing capacity checks after the MRP processing. RCCP makes use of a bill of resources for each end item on the MPS. The bill of resources gives the number of hours required at each critical resource to build a particular end item. CRP provides a more detailed capacity check on MRP-generated production plans. Necessary inputs include all planned order releases, existing WIP positions, routing data, as well as capacity and lead times for all process centres. It does not generate finite capacity analysis. Instead, CRP performs what is called infinite forward loading. It predicts job completion times for each process centre, using given fixed lead times, and then computes a predicted loading over time. (Hopp, W. J., Spearman, M. L. 2011)

Short term control has only three parts, job release, job dispatching and input/output control. Since the planning is done in previous levels, this part focuses on implementing and control. In job release function the planned order releases are converted into scheduled receipts. Job release focus a lot in allocation, how to solve conflicts in manufacturing. Job dispatching means the rule or strategy used to direct the orders for each workstation. Input/output control monitors the WIP level in each process centre and adjusts the release rate by changing the MPS. (Hopp, W. J., Spearman, M. L. 2011)

3.4.1 Planning and control system

Jacobs (2011) visualizes the manufacturing planning and control system in Figure 6. The planning and control is divided to three levels: Front end, Engine and Back end. These levels represent the company operation levels. Front end is the management level, Engine is the level of intermediate planning and back end the operations level.

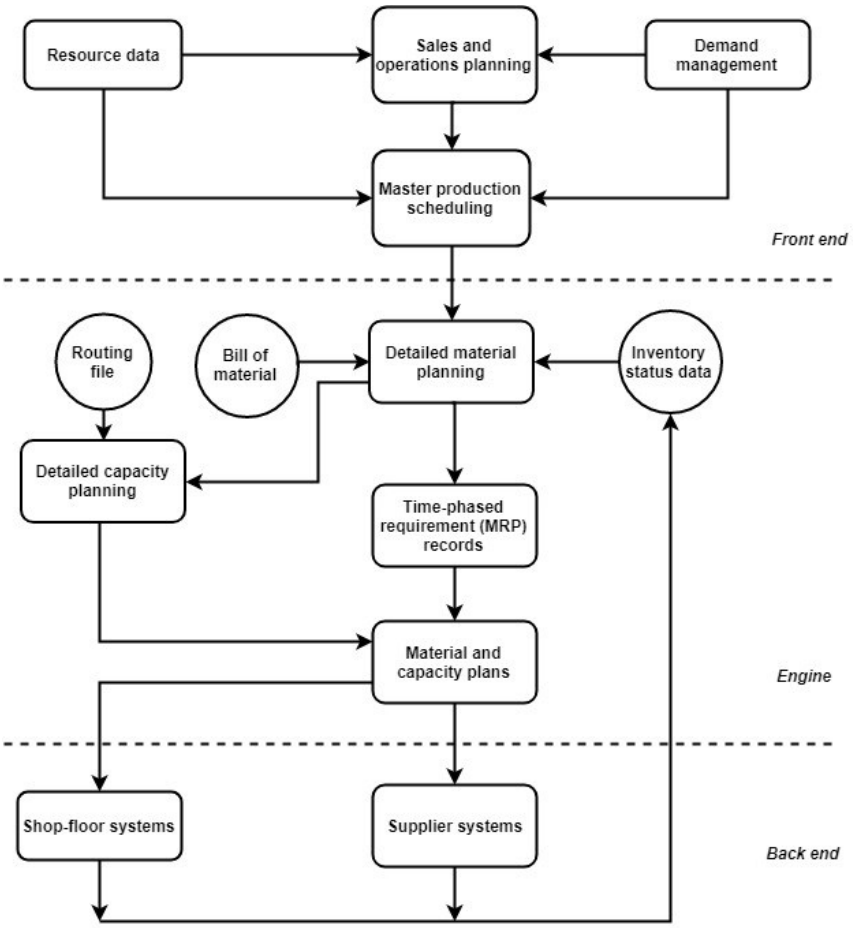

Figure 6 Manufacturing Planning and Control System (Jacobs, 2011, p.216)

In Front end the capacity is only considered in a very rough mater, in resource planning. The data form resources is combined with data from Sales and Operations planning and Demand management in the MPS.

In engine level the capacity planning is in more detail considering more comprehensive material planning, inventories and routings. The plan made with MPS is combined with BOMs and inventory data to create a detailed materials plan. This plan is then combined with routing information to create a detailed capacity plan. It is also used for MRP. At the end of the Engine planning level is where these two plans meet for a Material and capacity plans.

In back end, the Shop-floor systems do scheduling of orders that consider more finite loading and suppliers system use these plans for their production planning. Both of these plan affect the status of the inventory.

3.4.2 Time horizon

Depending on the time horizon, the significance of the planning and control varies. As Figure 7 displays, in long-term the planning takes a lot larger part than control. It uses accumulated forecasts of demand and controls resources as a combined system. This could mean for example all products counted together and with a rough estimation of resources available. Financial goals are set based on the long-term plan.

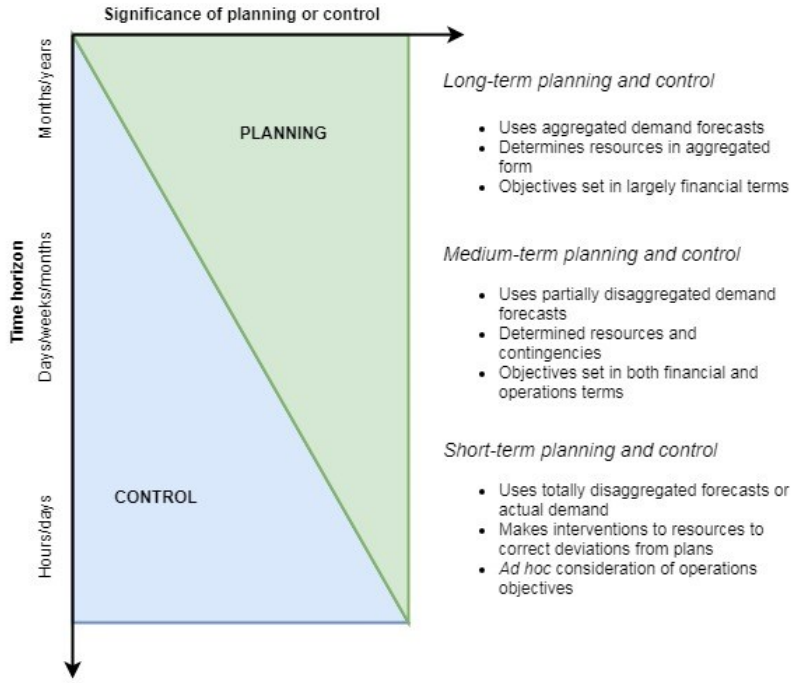

Figure 7 The balance between planning and control activities changes in the long, medium and short term (Slack et al. 2011, p. 226)

Medium-term is between two extremity and uses combination of planning and control. The methods used are also blends of the methods used by the phases in other ends. This means partially disaggregated demand forecasts, for example in different products. The resources are determined and contingencies made. The objectives are established in financial and operational terms.

In short-term horizon, there is not much use for planning, but to control the production. It uses detailed forecasts and information of actual demand and only intervenes with resources to precise unconventionality.

As in many examples before, many companies divide the planning of manufacturing to three phases. These phases are listed in the table 1 below. One way to divide the planning is by the planning horizon: long term, mid-term and short term. All of these phases are used for different purposes.

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Table 1 Production planning horizons (Hopp, 2001, s. 410)

Time horizon	Area of influence	Length	Representative decisions
Long term	Strategy	Year to decades	Financial decisions Marketing strategies Product designs Process technology decisions Capacity decisions Facility locations Supplier contracts Personnel development programs Plant control policies Quality assurance policies
Intermediate term	Tactics	Week to year	Work scheduling Staffing assignments Preventive maintenance Sales promotions Purchasing decisions
Short term	Control	Hour to week	Material flow control Worker assignments Machine setup decisions Process control Quality compliance decisions Emergency equipment repairs

Long term plan can be from one year to decades, is used for making big decisions and as a base for strategies. For example these decisions include choices about large financial, marketing strategies and product design, all the large decisions that affect the companies for years to come.

Intermediate term planning or mid-term planning in short can be from a week to a year. It is used more in tactical decision making and planning. The decisions made based on this plan are more about scheduling work and staffing and planning maintenance and sales promotions.

Short term planning is form hour to a week plans and it is used more in controlling the manufacturing. The plan is more detailed so only small decisions can be made based on it, such as control of materials and processes in a factory. The table 1 lists more what decisions are made from each planning horizon

3.4.3 Parameters affecting the planning

In Figure 8 the hierarchy of production planning and control for a pull system is presented. In the long-term strategic phase the forecast is made with plans for capacities, facilities and workforce. In this phase also the aggregate plan is made. All these processes are used for strategic decisions. In mid-term planning methods needed for tactical decision making are located. These include demand management, MPS with sequencing and scheduling. At the bottom is the production control that is done in short term only. It includes real-life simulation, shop floor control and production tracking. Of course all these phases work together and share information.

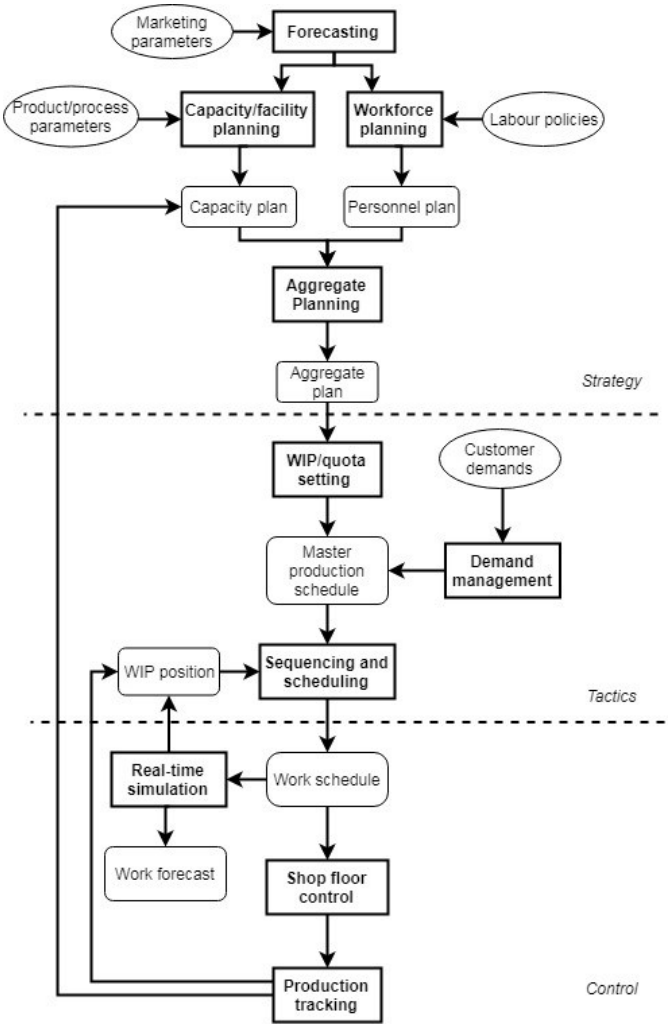

Figure 8 A production planning and control hierarchy for pull systems (Hopp, 2001, s. 433)

Different parameters, policies and restrictions affect the planning process in different levels. These constraints are often something that the company have no influence to. The Figure 8 above shows these where these limitations have effect.

The marketing parameters affect the forecasting by setting the constraints to the forecast. Parameters such as plans for the company to grow needs to be considered when making the forecast more accurate. It is important to have as accurate plan as possible, because this forecast affects all strategic decisions.

When the demand is forecasted, it can be taken to plan for needed capacity. The capacity can be divided to two parts, the capacity and facility and workforce. The capacity planning in facility planning is dependent on the product and process parameters. The product parameters such as BOMs and BOLs affect the production and capacity. These capacity and facility planning make a capacity plan.

The labour policies affect the workforce planning. The forecast gives an estimation of how much labour is needed to cover the demand. Many labour policies state that the personnel plan needs to be published before certain amount of time.

The capacity plan with the personnel plan is used in the aggregate planning process. The plans give an idea if strategic modifications are needed. By combining the capacity plans to forecast the aggregate plan is shown how to plan the production. It is done in a high level aggregated because of the uncertainty of the forecast. It includes rough predictions about the product mix and volume. Strategic decisions are about making changes to the parameters affecting the plan. For example acquiring more capacity as getting another production facility or outsourcing a part of the process. The decisions can be of moving the personnel or hiring personnel needed to have enough capacity to fit the forecast.

To bring the plans to intermediate level, from strategy to tactics, more information is added. This starts with WIP/quota-setting module. This process decodes the aggregate plan into card counts in pull system and periodic production quotas. The production quotas are then used for the MPS as disaggregated plan. This means that it uses the disaggregated forecast but also customer orders.

The customer orders used in MPS come from the demand management module. This module takes firm customer orders which are smoothened appropriately. The demand in some level is again aggregated but this time in actual demand. The MPS is translated into work schedule in the sequencing and scheduling module. This work schedule determined what should be produced in near term. The customer orders are arranged based on the dispatching rules and set to facilities. Tactical decisions in this scheduling can be made in the order in which the orders are proceeded.

The lowest level of the hierarchy is about the production control. The shop floor control module does just that: it controls the flow of material through the production plant in real time and checks that it is according to the schedule. The production tracking helps with this by measuring the actual progress against the schedule. This information can be used as feedback information back to the planning system. This way if something unexpected happens, it can be reacted to. The real-time simulation module can be used for creating simulations of different production simulations. This way the planner can compare different what-is scenarios and select the optimal alternative.

3.4.4 Planning process

The process of finite capacity planning is visualised in Figure 9. This process is more detailed than the three steps mentioned on page 12, but the main parts stay the same.

First, a due date is set for new jobs for scheduling. The restrictions for the plan are set, limiting the jobs included in the plan and the capacity available. This way the plan will not be infinite restrictions can be considered.

Then a rough draft is made as a MPS. The master productions schedule will schedule the jobs into a roughly feasible plan.

The jobs in this schedule are then prioritised so that the agenda can be made with certain ranking rules. This way selected qualities can be preferred and certain values optimised. The sequencing discussed later is used in this part of the process.

The finite capacity plan is then made concerning certain manufacturing restriction. This has a more aggregate plan and the plan per items.

Normally there are always exceptions that need to be manually moved in the schedule. By manipulating the plan, orders can be moved up or down. These exceptions can be orders that are treated differently from the usual, so the standard prioritising methods do not apply.

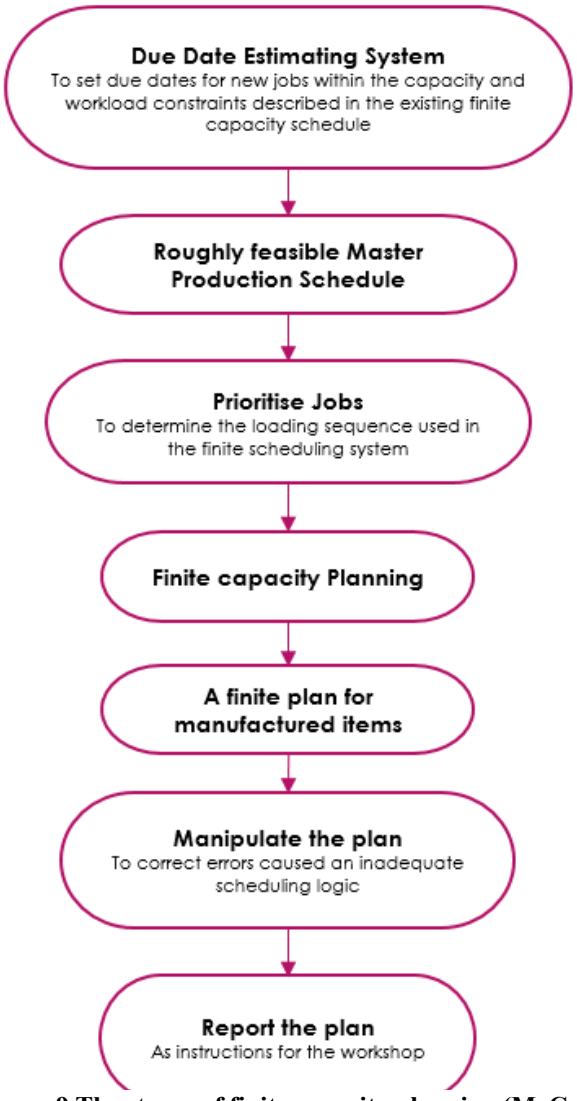

Figure 9 The stages of finite capacity planning (McCarthy, S.W., Barber, K.D., 1990)

When the plan is ready, it should be shared with the stakeholders so that the information is spread. The plan must go to execution and the workshop use it as instructions.

The report of resource management capacity plan looks something like in Figure 10 about resource management capacity reporting. The plan should demonstrate that the production capacity is not exceeded. The plan displays what is the production capacity, how much of it is used, promised and available to promise during a specific time period. With this information, it is easy to see how the capacity is developing and how much is available. Figure like this could be used for the total capacity usage, capacity per supplier or even by product. Capacity per supplier tells more about the situation that one of the supplier have. Capacity

per product would show the production status for a product, considering for example material statuses. More detailed report would show a production capacity per supplier per product.

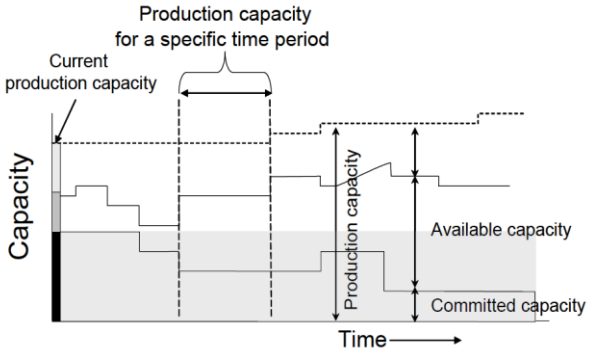

Figure 10 Resource management capacity reporting (ISA-95)

The input and output measures for capacity depend on the situation. Many times there is a possibility to select from different alternatives of measurement. The best one is something that makes the capacity clear, understandable and measurable. Figure 11 below lists some measures of capacities used in different situations. The most common ones are shown in bold font and are measurements that are discrete, such as beds available in a hospital or number of units manufactured in a plan.

Operation	*Input measure of capacity*	*Output measure of capacity*
Hospital	**Beds available**	Number of patients treated per week
Theatre	**Number of seats**	Number of customers entertained per week
University	**Number of students**	Students graduated per year
Retail store	**Sales floor area**	Number of items sold per day
Airline	**Number of seats available on the sector**	Number of passengers per week
Air-conditioner plant	Machine hours available	**Number of units per week**
Electricity company	Generator size	**Megawatts of electricity generated**
Brewery	Volume of fermentation tanks	**Litres per week**

Note: The most commonly used measure is shown in bold.

Figure 11 Input and output capacity measures for different operations (Slack, et al., 2011, p. 232)

3.4.5 Planning and scheduling

One of the mail features in scheduling are the dispatching rules. These rules, also referred as sequencing, are the operation decisions about the order in which the inputs are handled. This means that the schedule is based on certain rules.

There are many different values and parameter that are needed in scheduling. Some of these values are not dependent on the schedule but fixed before. This means that these values cannot be altered in the schedule. Then there are those values that are only set in the process of scheduling.

Work orders, or jobs are a sets of work that need to be processed together. For example this could mean customer orders or just batches of products.

Sequencing

Dispatching rules, or sequencing are the rules used for prioritising jobs. The sequencing set the orders and jobs to a certain order. Many times a set of these rules are used to find the optimal solution, not only one.

Customer priority
In some cases, some customers are more valuable than others. An important customer will be served prior to other customers, no matter what the arrival order is. This is typical if the customer base is skewed in a way that there are many small customers and some very large important customers. This can be also seen in airports with first class customers, where certain people with priority cards get service first. (Slack et al. 2011, p. 232)

Physical constraints
Physical constraints may determine the priority of work. For example when using paints or washing clothes, it is good to start with lighter colours. (Slack et al. 2011, p. 232)

Earliest Due Date (EDD)
Prioritizing by the due date means processing by when the product is due for delivery. This rule increases the delivery reliability and improves average delivery speed, however the productivity might not be optimal. In cooking, this rule might be the only one working. (Slack et al. 2011, p. 232)

Last-in first-out (LIFO)
LIFO is a dispatching rule where the product that is worked with first is the last one to arrive. This rule is many times selected for practical reasons. For example unloading of an elevator. When people are involved, they are not happy. (Slack et al. 2011, p. 232)

First-in First-out (FIFO)
Orders are sequenced in the order of arrival. This dispatching rule is sometimes also referred as Fist come, first served (FCFS). For example service in a regular cafeteria. (Slack et al. 2011, p. 232)

Longest operation time (LOT)
This method will keep work centres occupied for long times. It increases utilization, however delivery speed, reliability and flexibility suffer. (Slack et al. 2011, p. 232)

Shortest operation time first (SOT)
Larger jobs that take more time will not enable the business to invoice as quickly and in these situations, the sequencing rules may be adjusted to operate short jobs first in the system, called shortest operation time. These jobs can then be invoiced and payment received to ease cash flow problems. This has an effect of improving delivery performance, if the unit of measurement is delivery of jobs. However, it may affect total productivity and can damage service to larger customers. (Slack et al. 2011, p. 232)

Comparing sequencing rules

Performance objectives can be used to evaluate the effectiveness of these rules. The objectives of dependability, speed and cost are the most important and commonly used. For example, the following performance objectives can be used: Meeting 'due date' promised to customer, maximising dependability; Minimizing the time the job spends in the process, also known as 'flow time'; Minimising work-in-progress inventory; Minimizing idle time of work centres. (Slack, et al, 2011,p. 232)

Values used for scheduling

For making a schedule specific values are compulsory. Pinedo divides the data required to two groups: static and dynamic. Static data is the information that does not depend on the schedule. These values are set before the scheduling. This type of information includes the Processing Time, Release Date, Due Date and Weight. The Processing Time means the time a certain job has to spend time in a certain operation. The Release Date of a job is the time the job arrives at the system that is basically the earliest time the job can be started to process. Due Date represents the date the job is promised to the customer and needs to be completed. Completion after the jobs due date is allowed but comes with a penalty. If it is not allowed, but the due date is an absolute, it is referred as a deadline. The Weight does not mean that physical weight of a job but a priority factor of one. The value reflects the importance of the job relative of other jobs in the system. For example it could be the inventory cost or value added to the job. (Pinedo, 2009, p. 22)

Dynamic data is the data that is not fixed in advance and depend on the schedule. Pidedo lists Starting Time, Completion Time, Single Machine Models, Parallel Machine Models, Flow Shop Models, Job Shop Models and Supply Chain Models the most important ones. Starting time is the time when the job start processing in the schedule. Completion time is when the job has completed a process in the schedule. These values have freedom of action which means that the jobs can be scheduled to start even earlier than necessary, or even late if necessary.

Figure 12 Single Machine Models

Single Machine Models are used also in cases where there are in fact more than one machine to use. An example of this is shown in Figure 12. Single Machine Model is a way to simplify scheduling when in fact only the bottle neck of production is scheduled. This bottleneck has been analysed to determine the performance of the entire system. This way the schedule for the bottleneck is set first and other operations based on that schedule. In these cases the EDD rule has been noticed to minimize the maximum lateness among all jobs, when SPT rule minimizes the average number of jobs waiting for processing.

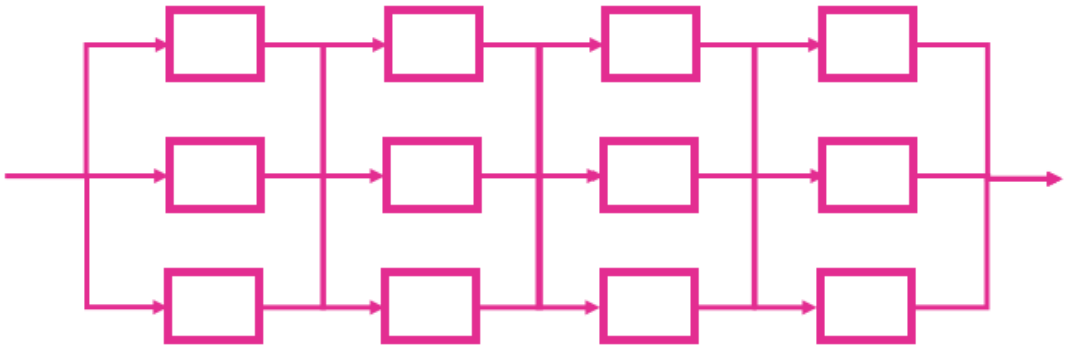

Figure 13 Parallel Machine Model

Parallel Machine shops are a generalisation of single machine model, as shown in the Figure 13 above. Many production environments consist of several stages with multiple machines per stage. When a job comes to the stage, it has multiple options to choose from. The parallel machines might not be exactly identical. This could mean that for example the processing times vary between machines. There is also a possibility that certain jobs can only be processed with certain set of these machines, or by certain operators.

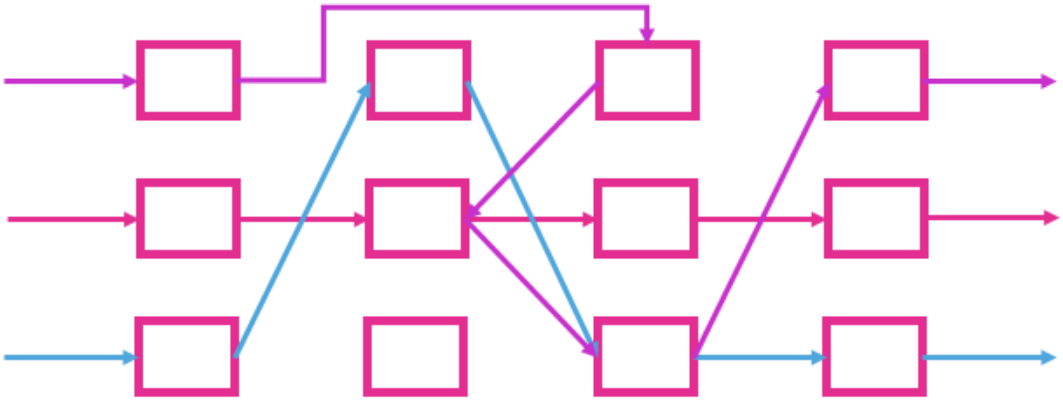

Figure 14 Job shop

Flow Shop Models are used in manufacturing sited where the jobs go under multiple operations on a number of different machines. The manufacturing environment is referred as a flow shop, if the routes of all jobs are the same. Flexible flow shop is a generalization of the previous whereat each stage a job may be processed any of the machines in parallel or even bypass a stage. Job Shop Model is a manufacturing environment with multiple routes. At simplest this means that a job can be processed at most once on a particular machine through its route. In flexible job shops work centres have multiple machines in parallel and recirculation is possible. This kind of solution is visualised in the Figure 14.

Supply Chain Models is a more general model with network of interconnected facilities. Planning and scheduling in this level may focus on actual production in the facilities and the transportation of products between facilities. Figure 15 shows a Supply Chain model visualised. (Pinedo, 2009, p. 23)

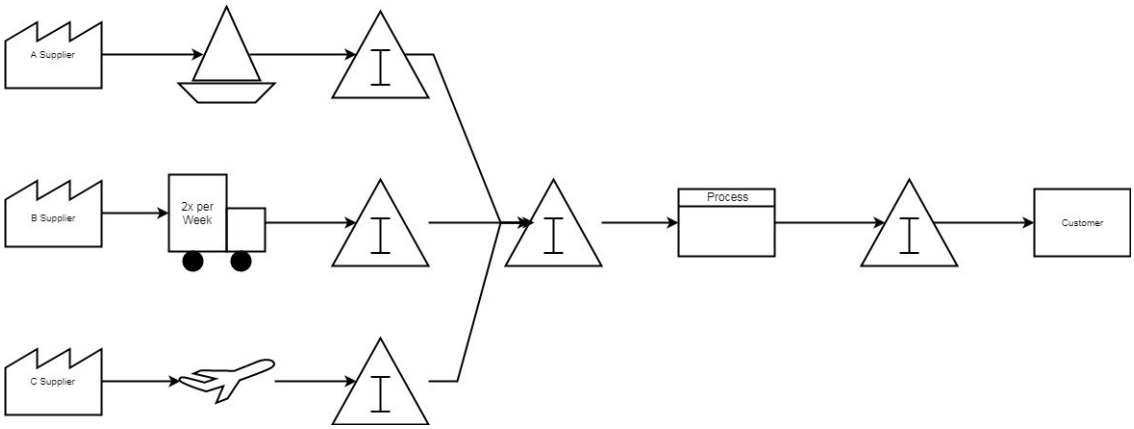

Figure 15 Supply Chain Model

Pinedo also lists processing characteristics and constraints: precedence, machine eligibility, workforce, routing. Precedence constraints are a set of steps that need to be completed before the job can start. These could mean for example that parts be to be manufactured before the assembly can start, or an order needs to be made before assembly in a pull system. Machine Eligibility constraints is when in a parallel machine environment a job cannot be processed by any machine, but only a subset of machines. Workforce constraints are similar but with workforce, there are only specific operators that can work with certain machines or jobs. Routing constraints specify the route a job must follow. This could mean a certain sequence or order of operations.

Material handling constraints are the handling systems of materials that convey materials from one workstation to another. The system is highly dependable on the starting time of an operation and the completion of its predecessors. Sequence Dependent Setup Times and Costs are just that, the times and costs that are caused by other activities than processing jobs. This could be set ups between jobs, reconfigurations or cleaning for example. These actions take processing time, cost of labour and raw material. Storage space constraints the production by limits about of space. Many times there are limits on how much storage is available for Work-in-process. If the storage is full, this could cause blocking.

Waiting Time constraints relate to the same thing, the waiting to be processed cannot take for ever. Even if there is space available, the stock should not be gathered. The production strategy, meaning Make-to-Stock and Make-to-Order affects the scheduling greatly. It gives the customer decoupling point in which the scheduling starts from. Pre-emptions are actions done to interrupt processing of one job to make way for another. Transportation Constraints are about the network of facilities. This constraint applies especially for supply chain planning. The transportation from a manufacturer to the customer is something that affects the production schedule greatly. (2009, p. 24)

3.4.6 Scheduling integrated Medium Term Supply Chain Model

An example of a similar scheduling problem to Lindströms case is introduced. This is an example of a supply chain with three stages. The first stage, Level 1 has two factories working in parallel. The factories produce two products, F1 and F2. The factories are run 24 hours seven days a week putting the total production capacity of 168 hours a week. Level 2 is the distribution centre (DC) and Level 3 is the final customer. This supply chain is shown in Figure 16 below. The chart shows that products are also delivered to the final customer straight from the factory. In this example the factories have no room for finished goods storage and the customer does not want to receive deliveries early. The medium term plan is for production timing and quantities that minimizes the total cost of production. This includes the storage cost, transportation cost, tardiness cost. These costs are considered for the whole supply chain over a four week time horizon using one week as a unit of measurement. In this example, all transportations are assumed to be identical an equal to one week. (Pirim, et al., 2014)

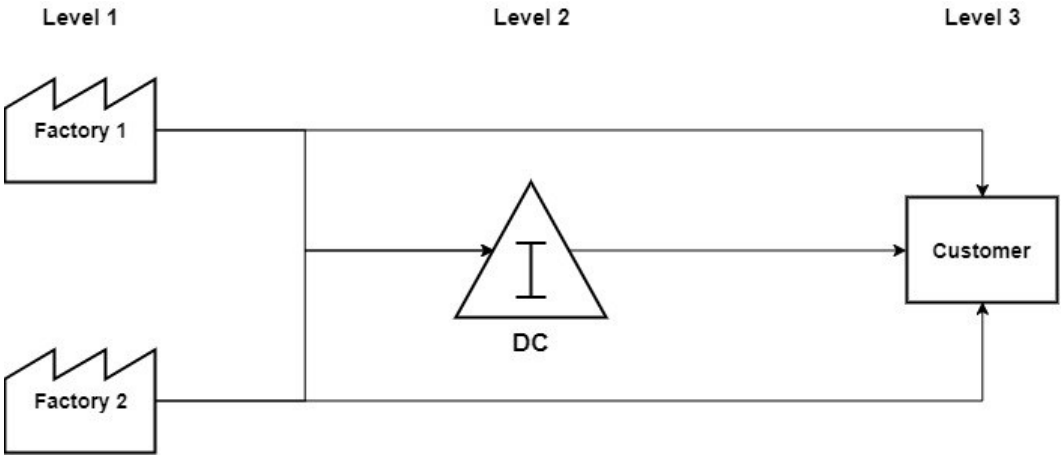

Figure 16 A supply chain with three stages (Pirim, et al., 2014)

Parameters and inputs used for the scheduling:

j	product j, j = 1,2
l	level l, l = 2,3
i	week i, i= 1,2,3,4
k	factory k, k = 1,2
D_{ijl}	demand for product j
tp_{jk}	time (in hours) to produce 1000 units of family j
cp_{jk}	unit cost of producing part j in factory k
cs	unit storage cost in DC of any product type
$c\tau 1_k$	unit cost of transportation from factory k to DC
$c\tau 2_k$	unit cost of transportation from factory k to the customer
$c\tau 3$	unit cost of transportation from DC to the customer
$t\tau$	transportation time between any two levels is assumed to be one week
TD_j	tardiness penalty per unit per week of product j that arrive late at the DC
TC_j	tardiness penalty per unit per week of product j that arrive late at the customer

TT Penalty for never delivering one unit of product
(Pirim, H., Al-Turki, U., Yilbas, B.S., 2014)

Decision variables used for the scheduling:

x_{ijk} number of units of product *j* produced at plant *k* during period *i*
y_{ijk2} number of units of product *j* transported from plan *k* to the DC in week *i*
y_{ijk3} number of units of product *j* transported from plant *k* to customer in week *i*
z_{ij} number of units of product *j* transported from the DC to the customer in week *i*
q_{0j2} number of units of product *j* in storage at the DC at time 0
q_{ij2} number of units of product *j* in storage at the DC at week *i*
v_{ij2} number of units of family *j* that are tardy, meaning have not yet arrived, at the DC in week *i*
v_{4j2} number of units of product *j* that have not been delivered to the DC by the end of the planning horizon, week four
v_{0j3} number of units of product *j* that are tardy at the customer at time 0
v_{ij3} number of units of product *j* that are tardy at customer in week *i*
v_{4j3} number of units of product *j* that have not been delivered to the customer by the end or the planning horizon, week four
(Pirim, H., Al-Turki, U., Yilbas, B.S., 2014)

Constraints

There are constraints in the form of upper bounds UB_{jkl} and lower bounds LB_{jkl}on the quantities of product *j* to be shipped from plant *k* to stage *l*. (Pirim, H., Al-Turki, U., Yilbas, B.S., 2014)

The objective function

The object being to minimize the total of production costs, storage costs, transportation costs, tardiness costs and penalty for non-delivery with planning horizon of four weeks. In this example Mixed Integer Program is used.

The function is to minimize:

$$\sum_{i=1}^{4}\sum_{j=1}^{2}\sum_{k=1}^{2} cp_{jk}x_{ijk} + \sum_{i=1}^{4}\sum_{j=1}^{2}\sum_{k=1}^{2} c\tau 1_k y_{ijk2} + \sum_{i=1}^{4}\sum_{j=1}^{2}\sum_{k=1}^{2} c\tau 2_k y_{ijk3} + \sum_{i=1}^{4}\sum_{j=i}^{2} c\tau 3 z_{ij} + \sum_{i=1}^{4}\sum_{j=i}^{2} csq_{ij2} + \sum_{i=1}^{3}\sum_{j=i}^{2} TD_j v_{ij2} + \sum_{i=1}^{4}\sum_{j=i}^{2} TC_j v_{ij3} + \sum_{j=1}^{2} TTv_{4j3} + \sum_{j=1}^{2} TTv_{4j2}$$

Subject to

Weekly production capacity constraints in hours:

$$\sum_{j=1}^{2} tp_{j1} x_{ij1} \leq 168, \qquad i = 1,2,3,4;$$

$$\sum_{j=1}^{2} tp_{j2} x_{ij2} \leq 168, \qquad i = 1,2,3,4;$$

Transportation constraints:

For each, *ijl*, $i = 1,2,3,4$; $j = 1,2$ and $l = 2,3$:

$$y_{ij1l} \leq UB_{j1l}$$
$$y_{ij1l} \leq LB_{j1l} \; or \; y_{ij1l} = 0$$
$$y_{ij2l} \leq UB_{j2l}$$
$$y_{ij2l} \leq LB_{j2l} \; or \; y_{ij2l} = 0$$

In addition to:

$$\sum_{l=2}^{3} y_{ijkl} = x_{ijk} \qquad i = 1,2,3,4; \quad j = 1,2; \quad k = 1,2;$$

$$\sum_{k=1}^{2} y_{ijk3} + z_{ij} \leq D_{i+1,j,3} + v_{ij3} \qquad i = 1,2,3; \quad j = 1,2;$$

$$z_{1j} \leq \max(0, q_{0j2}) \qquad j = 1,2;$$

$$z_{ij} \leq q_{i-1,j,1,2} + y_{i-1,j,2,2} \qquad i = 2,3,4; \quad j = 1,2;$$

Storage constraints:

$$q_{1j2} = \max(0, q_{0j2} - D_{1j2} - z_{1j}) \qquad j = 1,2;$$

$$q_{ij2} = \max(0, q_{i-1,j,2} + y_{i-1,j,1,2} + y_{i-1,j,2,2} - D_{ij2} - z_{ij} - v_{i-1,j,2}) \qquad i = 2,3,4; \quad j = 1,2;$$

Constraints regarding number of jobs tardy and number of jobs not delivered:

$$v_{1j2} = \max(0, D_{1j2} - q_{0j2}) \qquad j = 1,2;$$

$$v_{ij2} = \max(0, D_{ij2} + z_{ij} + v_{i-1,j,2} - q_{i,j,2} - y_{i-1,j,2,2}) \qquad i = 2,3,4; \quad j = 1,2$$

$$v_{1j3} = \max(0, D_{1j3}) \qquad j = 1,2;$$

$$v_{ij3} = \max(0, D_{ij3} + v_{i-1,j,3} - z_{i-1,j} - y_{i-1,j,1,3} - y_{i-1,j,2,3}) \qquad i = 2,3,4; \quad j = 1,2$$

This example is very comparable to the supply chain scheduling that is sought from this project. It presents an example of how the optimisation is prepared in a scheduling system. This is a very classical case of linear model used for scheduling. All the parameters, variables and constraints are very familiar to Lindströms case.

3.5 Benchmarking

In this chapter capacity planning and production planning is examined in different benchmarking companies.

3.5.1 Production planning and control in Finnish manufacturing companies

A few years back, a survey study about Production planning and control in Finnish manufacturing companies studied its current state and challenges. Researchers from Tampere University of Technology, Aalto University School of Engineering and VTT interviewed 25 Finnish manufacturing companies between 2013 and 2014. Their main findings were that modern IT-tools for MOM, including MES and APS systems were still rare. (Järvenpää, et al. 2015)

The detailed production scheduling, dispatching and operations control are commonly performed by various MS Excel spreadsheets and paper documents, which are not integrated with other company IT-systems and do not support rapid reaction to changes and disturbances. This deviation is presented Figure 17. (Järvenpää, et al. 2015)

Variation of companies included:

Table 2 Companies included

Company size	Type	Amount
SME (< 250 persons)	OEM (Own product)	8
SME (< 250 persons)	Sub-contracting	9
Large (> 250 persons)	OEM (Own product)	8

The interview consisted of a plant tour and interview of three types of personnel: plant or production manager, production worker and a main user of the production planning and execution system or an IT manager. (Järvenpää, et al. 2015)

When this research was started, two of the companies had a MES tool and one was preparing for a MES pilot implementation. None of the companies had a exact APS-system that can be used to simulate different schedule scenarios. The companies used ERP, Excel or pen and paper to plan and schedule production. The problems experienced were that ERP does not support capacity restricted planning and spreadsheet were highly personified, meaning there are only few who can update and interpret it. Companies using pen and paper were not able to collect any detailed history data. Also when for some reason re-scheduling this needed, with Excel and ERP the process is very laborious. A mixture of these two requires manual updating and communication between different levels of the organization. The research states that majority of the companies were hoping to get rid of the unconnected excel sheets. (Järvenpää, et al. 2015)

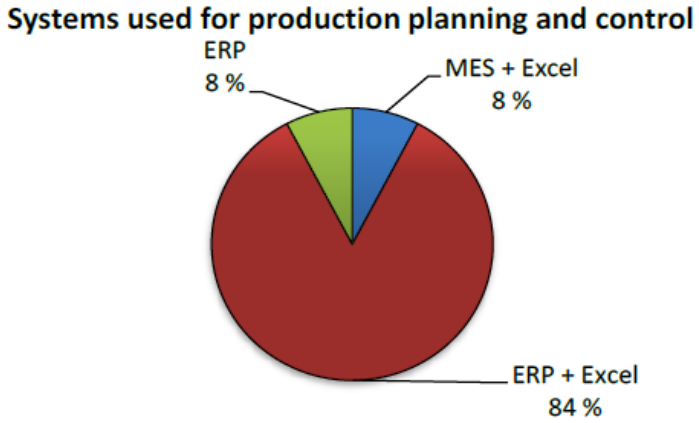

Figure 17 Systems used for production planning and control (Järvenpää, et al. 2015)

Many different strategies are used for material management in the interviewed companies. Repeated items such as bulk items and cases are commonly in pull control which is implemented as an alarm limit to ERP or visually. (Järvenpää, et al. 2015)

In OEMs especially the components and materials are replenished based on MRP calculated in ERP based orders. However if the lead time is long, the orders are based on forecasts. In small shops it is common that the employee forwards the information when a short supply is noticed. (Järvenpää, et al. 2015)

Majority of the companies interviewed, manage their material balances in ERP and many of them have problems with the management of inventory, especially with faulty balances. (Järvenpää, et al. 2015)

All companies have recognized the need to increase transparency in their production network. Majority of the large OEMs have gone as far as offer their closest sub-contractors and suppliers visibility to their ERP-system. But it only works one way, they did not have any visibility to their systems and the communication of changes in plans were done through emails and phone which seemed inefficient. (Järvenpää, et al. 2015)

Majority of the interviewees would like to increase the automation in order handling and start to use electronic orders. The email and telephone communication was seen problematic, because the information stays with the persons involved in the conversation, and it may never reach all the people that should be involved. For instance, different supplier portals were planned in many of the OEM companies. However, the information security issues were seen as a challenge. Increasing the transparency requires more trust and common rules. In order to enhance the information transparency, accessibility and information flows, most of the companies mentioned a desire to get rid of multiple separated systems, meaning ERP and various excel spreadsheets. The use of one system throughout the organization require following common rules. (Järvenpää, et al. 2015)

3.5.2 Murata

Timo Kyllönen wrote his thesis about Capacity planning in semiconductor manufacturing in 2016. The study is used to analyse machine capacity and bottlenecks in the production for Murata production plant. His thesis included a very describing flow chart of Muratas S&OP,

that is shown in Figure below with less detail. At the end of this project an excel tool was created. The plan was that after the data quality issues have been handled, a better and more precise tool will be purchased. (Kyllönen, 2016)

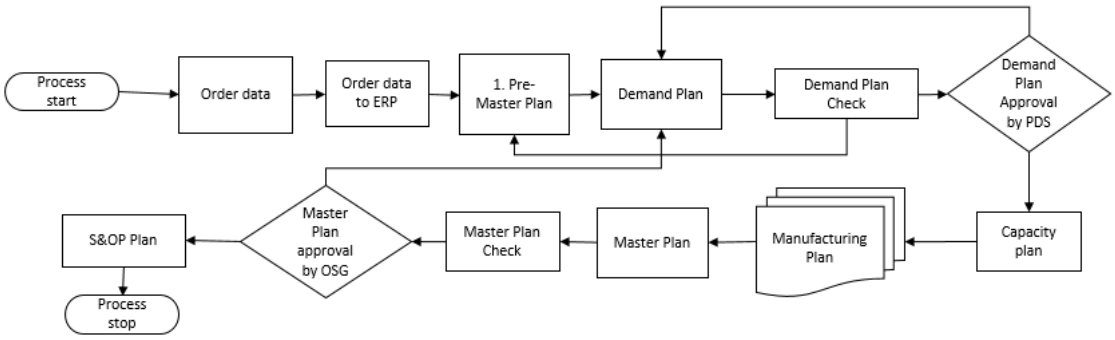

Figure 18 Murata S&OP (Kyllönen, 2016)

In Figure 18 Murata S&OP (Kyllönen, 2016) Muratas process starts with customer placing the order or a forecast of an order, sales offices receiving the data and it being linked to their ERP system. Murata does Pre-Master Plans quarterly for 18 months with data gathered from the ERP system. Based on that plan, a demand plan for present and new products is created. It can be used to map sales opportunities. The demand plan is then checked by the finance and business units, possible changes are updated to ERP and the plan is approved in a meeting.

Next comes the capacity plan that includes calculations done by production locations and production lines. The calculations are done with a software that is specifically designed for this task. The outputs are layout plans and outsourcing processes. The manufacturing plan includes purchasing sourcing plan, plan about new equipment investments, production support functions, operator and production shifts systems and material and end product stock plans. The Master Plan is an aggregated plan which includes the demand plan, capacity plan and manufacturing plan. It is then checked and approved. S&OP Plan is the agreed and updated supply plan for all manufacturing units. (Kyllönen, 2016)

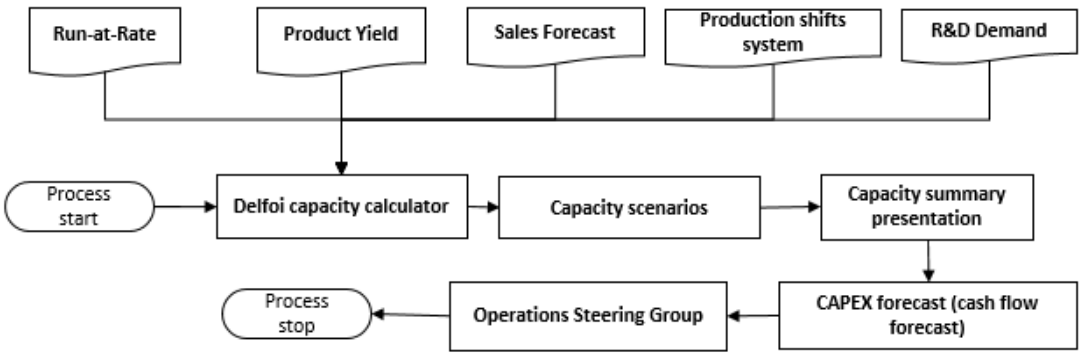

Figure 19 Murata Capacity Calculation Process (Kyllönen, 2016)

Muratas capacity calculation process is shown in Figure 19 Murata Capacity Calculation Process (Kyllönen, 2016) Information about the updated equipment ability to produce quality at capacity and utilisation rates, process step yields. This information comes from process quality control management. The next input is the product yield. This consist of the updated

yield percentage per element or product types. The information comes from the process development department. From Sales Forecast, the S&OP plan for one to 18 months and mid-term plan for sales forecast up to three years. Information about updated shift system per production lines are gathered from production management. Also information about R&D Demand such as new product production demand are needed for capacity planning.

At the beginning of the Murata Capacity Calculation Process, all this data is enrolled to the Delfoi capacity calculator. The calculator creates a model of the factory that includes process flows, equipment, demand time shifts and customer parameters. Different capacity scenarios are created with iterations between the equipment and processes, products and production lines. In this phase, the bottlenecks are analysed and layouts planned. Proposals for new investments and shift systems are made. Then the summary for combined capacity presentations and layout plans are made. These presentations include information about actual and customer required additional capacity needs, also the status of the capacity plan and equipment investment proposals with timing. A cash flow fore-cast follows. It includes the progress of investments and planned investments. The last step of the capacity calculation process is the Operations Steering Group. It includes further clarification requests, the approvals of capacity and equipment investment proposals, layout plan approvals, resource planning and equipment investment follow up.

For the biggest issues Kyllönen mentioned the variability of products. Another was the difference between different equipment, older machines take more time to finish a job that new ones. The product development projects also change the plans and are hard to forecast.

3.5.3 Martela

Ville Leinonen did his thesis to Martela just now 2017. This thesis only concentrates on safety stock levels on vendors. The idea was to get a tool that can be used when negotiating with vendors about how much they should keep in shock demand fluctuates.(2017)

Martela keeps the time of deliveries promised to customers much shorter than the time it takes to make the finished product from raw material. Because of this, Martela relies a lot in forecasts and needs to keep buffer storages. Their forecast cycle is an ongoing process that has four phases: executive Sales and Operation Planning (eS&OP), Preparation, Demand review and Supply review. This process is executed in monthly bases. It starts from Demand review, which is done by the sales team. The team creates a forecast based on past history, current offers that are still open and current order book. This forecast is made for only certain topliner product families in euros.

After sales team has completed their forecast they send it to the supply department. Supply department first divides the euro amount given for the entire product family and allocate the sum for specific product in the product family according to history events. After this they transfer the euro amount forecast into number of products and pass this information along to suppliers and Martelas own production. Next week from Supply review is eS&OP, where supply team reports to executive management latest status and what does the upcoming three months look like according to forecasts. After eS&OP, sales team and supply team starts to prepare for next month's cycle. In addition to these there is also an offering review that is done quarterly. The Martela eS&OP is presented in the Figure 20 below. (Leinonen, 2017)

Figure 20 Martelas eS&OP (Leinonen, 2017)

As many companies have noticed, also Martelas one major challenge is the continuously varying demand. For example, the demand of one type of table tops can vary from 500 units per week to over 1800 units per week just within four weeks. This creates enormous pressure to the whole supply chain and the S&OP process. Another challenge they have is the amount of different variations in their products that make supply chains complicated. (Leinonen, 2017)

3.5.4 Suunto

In STO seminar Juri Aapola, Suunto Supply Chain Director and Joakim Pelsán, S&OP Manager were presenting their world class capability planning. The different levels of planning is presented in Figure 21. The planning processes at Suunto are divided to three different phases: long term, mid-term and short term planning. Their long term planning considers next one to three years and it is used for future investments, distribution centre network and material vendors and make-or-buy decisions. They use values from budget and roadmaps for this sort of planning. Mid-term planning takes place for the next 1-12 months. The plan uses SAP and recently started using JDA software, which is used to create reliable forecasts of the demand. The mid-term plan is used to get a clear picture of material demand, number of employees needed and capacity needed. Short term planning horizon is 0-4 weeks. A MES- tool is used to plan and schedule the load in production cells. The tool creates a plan for a shift that is updated after every production shift. The goal of the short term plan is to guarantee the reliability of delivery and production efficiency.

For now a midterm planning process takes from one week to two weeks. The plan is created based on data from sales region that is compared to actual outcome and the budget. Reasonable changes to the plan are made and in the end of the process, a global 12 month plan is set in S&OP meeting. After accepting the plan, it is inserted to SAP BI by using excel based tool. This monthly plan is divided to weeks that make the production plan. The plan is used as a base for purchasing and capacity plans. The “unsold” production plan is deleted form the SAP every week, to stop it from generating excess inventory.

The challenges for mid-term planning have been the differences between used tool capabilities to process plans and long lead times of materials. There is also a difference what and

how often pre-information is collected. Also the amount of variability and short product life cycles make forecasting difficult.

Suunto is starting to use the statistical forecasting tool to make the forecasts better. In the tool, the historical data of an old product can be used as a base for the plan, and new products can have a ramp-down profile created. (Koskinen, 2017)

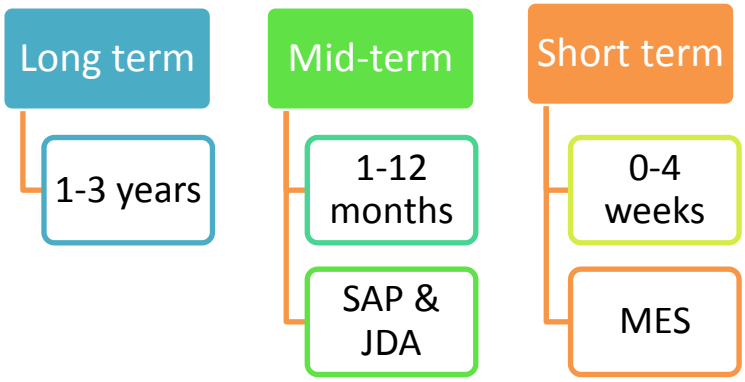

Figure 21 Suunto Capability Planning

4 Current state analysis

This report is about the current state of capacity planning at Lindström Oy. It focuses on the processes and tools that are linked to the mid-term capacity planning process. Lindström Oy has many procedures, such as demand planning and stock and procurement planning that affect the planning of the capacity. The actual procurement process that uses the capacity planned by the earlier phases in the whole planning process. There are many different software that are used in these processes as tools to gather information and to share it.

4.1 Roles

There are many stakeholders to processes involved in procurement planning. Chief Purchasing officer is the head of the procurement in Lindström. Respective Directors are responsible for the development of the sub processes. The CPO and the Directors form the Corporate Purchasing team. As the head of the team, the CPO is the owner of the Procure to Pay process and responsible for the operations of the Corporate Purchasing. Sourcing Director is responsible for the development and deployment of supplier development and management process. Purchase Director is responsible for development and deployment of the Order to Pay process and supply planning process. Supply Chain Director is responsible for development and deployment of the Supply Chain Planning and Execution Processes. Strategic sourcing director is responsible for uniform working methods and applying of the processes in the categories.

The heads of the multifunctional Category Teams are called Global Category Managers (GCM).The Categories under the leadership of Global Category Managers are responsible for the strategies and their annual action plans for the own product categories. The strategies are based on the Group level Procurement Strategy and analysis on markets and suppliers. The Global Category Manager is responsible for deployment and follow up of the category strategy and the annual action plan. On regional level the Heads of Procurement (HOP) are responsible for the Procurement in their region applying the Group level processes and the strategies of the Categories. (Nastamo, Pyhältö, 2017)

In the execution there are Logistics Coordinators, Buyers, Local Buyers, Demand Planner, Supply Planner and Project Managers. The Logistics coordinators handle the material flows of the central warehouses. Buyers handle the purchasing form suppliers. One buyer handles the procurement from a set of manufacturers, for example one buyer is dedicated to placing orders to Asian suppliers. Local buyers are set in each location and handle the buying from a business unit. They are also referred as Business Unit Buyers (BUB). Their purchasing include certain products, for example third party products that are not kept in stock. The Demand Planner is responsible for the demand planning process, whereas the Supply Planner is responsible for supply planning process.

4.2 Supply Chain

The supply chain processes are in between Service Operations and Order-to-Pay process for both planning and transaction execution from procurement point of view. The Sup-ply chain process' vision is to have an integrated, transparent, automatic and documented flow of information and goods. Lindström has three supply chain models that attend to different customer segments. (Rantanen, 2017)

Lindström has four different kinds of supply chains. The first line in the Figure 22 below shows the chain where the material is first purchased by Lindström, then the supplier uses this material to make the garments to Lindström. These products are then send to Lindströms stocking points. This way the availability of materials can be ensured especially in manufacturing points with long transportation times. These vendors are called CMT suppliers coming from Cutting, Manufacturing and Trims. In these occasions Lindström provides the supplier with fabrics and accessories to the garment. The supplier calculates the need of materials to Lindström based on the forecasts of products sent to the supplier.

The next supplier has only one major difference: the manufacturer of garments is Prodem, a Latvia based factory owned by Lindström. Latvia's location is perfect for European customers. The production there is fast and it can be observed in real time. Materials for manufacturing are naturally purchased based on forecasts.

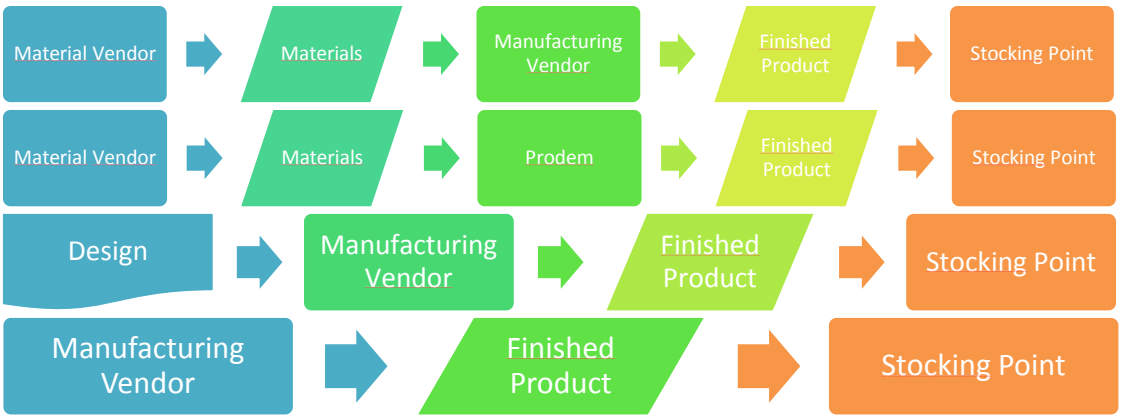

Figure 22 Lindström Supply Chains

Next comes the suppliers which order the materials needed and manufacture the garment based on design made by Lindström. In these cases Lindström has the authority to alter the product as much as needed and list the parts needed. The supplier delivers products to the stocking point as much as needed based on the purchase orders.

The last supply chain is for so called FP, Full Package suppliers. In this supply chain Lindström orders are already available collection from another company. The design is not owned by Lindström and there is no control over the production. These type of suppliers are used for products that are so basic that there is no point to design or keep it in stock. An example of products orders from these type of vendors are t-shirts in varying colours. There are so many vendors who have specialised in this sort of product and keep extensive stock.

Figure 23 shows Supply Chain models utilised by Lindström. There are three different supply chain models: Efficient, Dynamic and Flexible. The main difference is the location of

the customer decoupling point. Efficient supply chain model is used mainly for products with large volumes and low prices. The products have inventory in the central warehouse because they will be sold soon. All alterations to the product are changes that can be made in the laundry stock. The reason for selectin this type of supply chain model is for example long delivery times and price.

Dynamic supply chain model is for products that are not kept in stock and have a high conceptualization. The customer can order any product in their collection and have it altered. The third option is the flexible supply chain model that is always a one vendor solution with the lowest conceptualization and the reliability and consistency vary. In this model Lindström and the customer have very little to say about the product. In October 2017 the orders between these supply chains models were divided almost equally, meaning one third of the products ordered were from one of the types each.

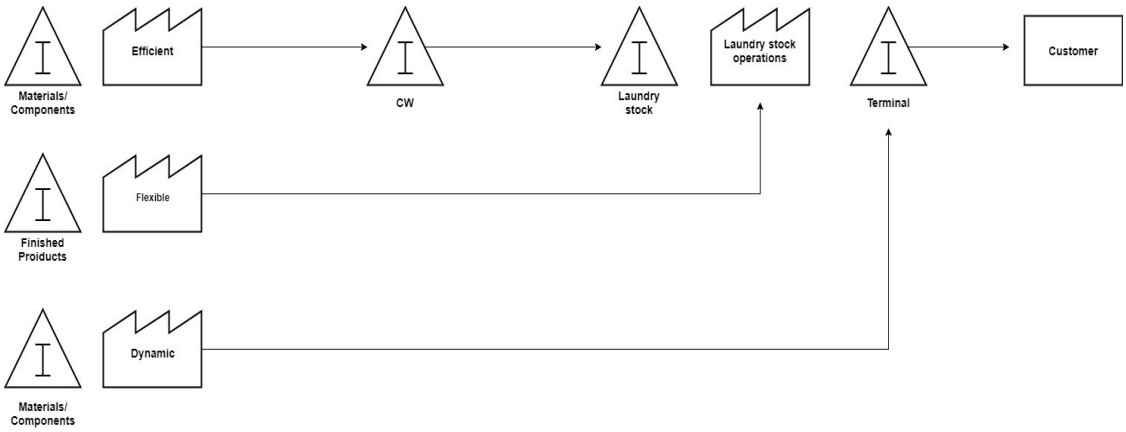

Figure 23 Lindström Supply Chain Models (Vahtera, 2017)

The products are also divided between these supply chain models. Best seller products are, as the name states, the best sellers. These products use the Efficient supply chain model where big batches of products are purchased from offshore suppliers. There is a customer promise to this kind of products stating that orders from 0-500 pieces are delivered in three weeks. This mean that even though there is stock in central warehouse, the products must also have the option to be manufactured in Prodem. The products using the Dynamic supply chain model are called Ready for sale. These products include Prodem products and other products that are not kept in stock. The last product category is Others. These products are the third party orders that use the Flexible supply chain model.

4.3 Software

Here the software currently used at Lindström are evaluated and the purposes are explained in procurement.

4.3.1 eLindström

A customer platform used is called eLindström. In this web page the customer can browse products selection, make orders and manage the workwear. Also customer service portal can use eLindström to enrol small customer orders. eLindström is currently used in Finland only. (Lindström, 2018)

4.3.2 Ritil

Ritil is a system used in laundries in Finland. The system has the information of products in stock for each laundry. This way when a small demand occurs, the supply of the laundry nearby can be used.

4.3.3 CRM

CRM comes from the words customer relationship management. CRM system is a system that is designed to manage and maintain customer relationship, track engagement and sales and deliver actionable data.

Figure 24 Customer Relationship Management (Petrides, P.D.)

Tools commonly used in CRM are:

- Centralize customer information
- Automate marketing interactions
- Provide business intelligence
- Facilitate communications
- Track sales opportunities
- Analyse data
- Enable responsive customer service (Microsoft, 2017)

Lindström uses Microsoft Dynamics 365 (D365) tool for customer relationship management. D356 offers CRM through five individual applications: Sales, Customer Service, Field Service, Project Service Automation, and Marketing.

Currently CRM is used in this process to provide procurement planner customer related data such as Customer information, Customer segments, Industry information, Collection-material-colour hierarchy, Opportunities, Open offers, Contracts and User group information in customer number level.

For capacity planning point of view, the most important qualities of the CRM are the Projects and Delivery Projects. In Projects new customers, new products to an old customer or product development projects are listed with information about the plan. This information includes the name of the project and the owner of the project. Additional information are start and end dates, project number and status, the customer account the project is linked to, project category, type, estimated value, description of the project and additional information.

Delivery projects are active projects that have a signed contract with the customer. These delivery projects include information about the order, the customer and schedule. Delivery projects also have information about the primary laundry for the customer.

Offers, Opportunities, Threats and Contracts are listed to CRM as uncertain customer projects. This way the possibility of these project can be taken into consideration in the forecasts. The probability and an amount of garments are set to a project. When the probability or the occurrence of the project is high enough, Quintiq considers the project in its demand estimations.

A project for developing a short term supply is starting soon. The purpose of this project is to add another module to delivery projects, where more information about the customer orders are collected. This information includes the products, sized and ordered amounts, all that is needed to make the purchase order. The project has not yet been scheduled.

4.3.4 Quintiq

Quintiq is a planning and forecasting system that is responsible for procurement planning functions such as demand planning, supply planning and inventory planning. At the moment Quintiq is used for planning in long-term, one month to 16 months. This plan shows the big picture of the production and purchase plan. The plan is made in two levels, the demand plan and the supply plan. Picture 20 shows the product aggregation levels used in demand planning and macro planning processes.

Quintiq was purchased so that unnecessary manual work could be eliminated from the procurement planning processes. With the sophisticated planning tool, the process and calculations will always be the same without too much personnel dependency and the planning process will be faster and repeatable. The business benefit will be achieved by having better forecasting accuracy at different planning levels. With more automatic planning, new supply chain models can be applied. This way the customer delivery accuracy will be better in the future. (Demand Planner – QBA)

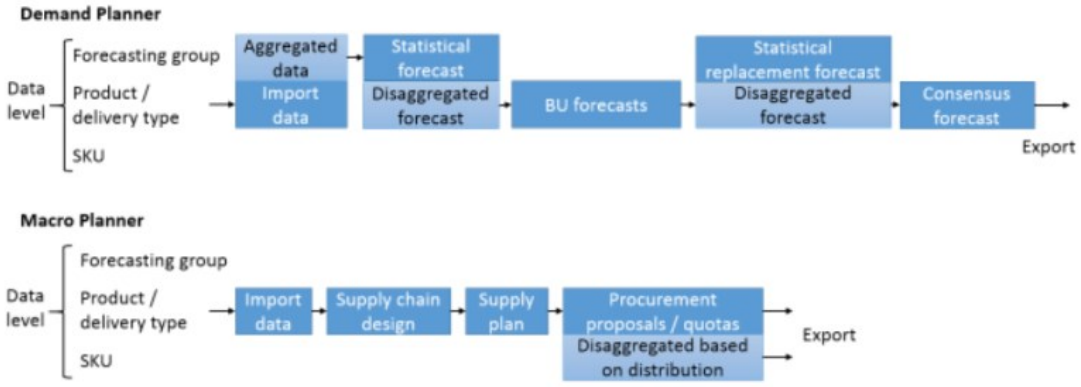

Figure 25 Product aggregation levels in the processes of DP and MP (Demand Planner – QBA)

The forecasting is done in three different kind of horizons. Unsurprisingly the level of detail in the plan decreases. From zero to four month the level of detail in the plan is in product level. The supply of specific products are planned based on history data and CRM data including product code level information about products to be delivered to the customer. From five to ten months before delivery to customer the plan shows raw material stocks and capacity needed from the suppliers. The plan includes the information on quantity, planned collections, main materials and colours of the products. The product level demand forecast is created 4 months before need at final stocking point, material level demand forecast is created 10 months before product need at final stocking point, demand forecast in pieces is created 16 months before product need at final stocking point and revenue forecast is created up to 16 months into the future. (Demand Planner – QBA)

Demand Planner

Demand Planner generates demand forecasts based on data from CRM and history. It is the main tool used in demand planning process. The end result of the plan is the monthly done Demand review.

The demand forecasting process is shown in Figure 26 below. The grey shapes are operations done outside the demand planned to create the lilac shapes that are input data used by the Demand Planner. Green shapes are operations done in the Demand Planner.

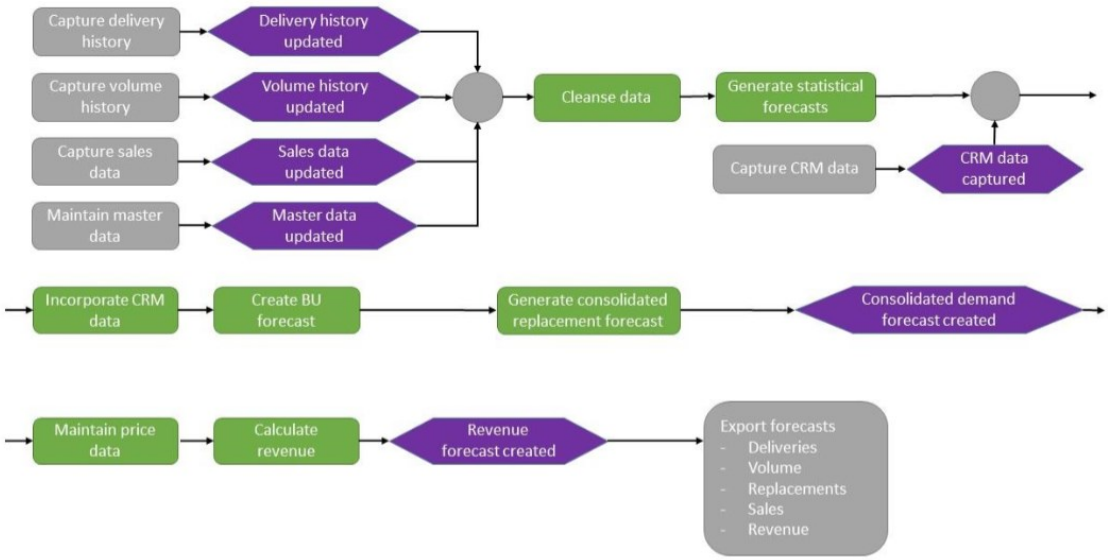

Figure 26 The demand forecasting process (Demand Planner – QBA)

Macro Planner

Macro Planner is the part of the Quintiq system where supply plans are created, optimised and compared. The main objective is to find the most efficient way to execute the sup-ply and fulfil the demand. Users can use the program to plan manually or with the pro-gram's built-in optimizer feature. Optimizer can be ran in different scenarios individually in order to compare different situations and outcomes. Comprehensive evaluation can be made by comparing the KPI's of different scenarios.

Macro Planner has a sanity check feature that offers an automatic and real-time data violation checking mechanism. The violations are categorized to five different groups that have a dif-ferent severity level: data issue, data warning, planning issue, planning warning, and unclas-sified error. Data issues have the highest severity level and unclassified errors the lowest. The reasons behind these issues and warnings should be checked before running the opti-mizer because they may result to a solution that is not actually optimal or even feasible.

The main users of Quintiq Macro Planner are Supply Planners in India and in Finland who makes the plan for the rest of the world. They use the plan made by the optimizer for different scenarios to plan for procurements and supplies. (Macro Planner Users Guide)

Figure 27 High level workflow of the supply planning process (Macro Planner QBA)

Macro Planner also considers On-the-way stock as supply. It takes information from Pow-ered, the purchasing system, about open purchase orders and the planned arrival dates of these orders. This way the plan will not estimate more demand than necessary.

The process of the supply plan is presented in the Figure 27 in a simple way. It will be explained more specifically in later chapters.

4.3.5 Powered

Powered is a production control system that is designed for industries. It is a Finnish industry oriented and reliable system that supports multi-site, multi-language production planning. (CGI, 2017)

In Lindström Powered is used for many tasks. In purchasing it is used for supplier in-formation, orders, purchasing prices and arrivals, also in reporting. In sales, it is used for sales orders, office orders and purchase product orders. It is also used in inventory management by having inventory values, availability inquiries and also reporting. It is integrated to central warehouse management. Powered also forms invoicing material for sales outside Finland. Powered has a supplier WEB feature that is used to inform the supplier of purchase orders and get information about the material supply, also purchase orders are confirmed with Powered. Subsidiaries use a Subsidiary WEB as well to save orders and forecast orders. Powered can also be used to create forecasts for materials needed and orders to suppliers. It creates base information for reports such as delivery reliability, central warehouse deliveries and balance management. (Powered, 2017)

Powered does not accept multiple pricing for the products. The regional prices are not considered in its functions.

D365 replacement of Powered as a purchasing system is scheduled to take place 2020.

4.3.6 PLM

Product Lifecycle Management is an information management system that can integrate data, processes, business systems and, ultimately, people in an extended enterprise. PLM software manages this information throughout the entire lifecycle of a product efficiently and cost-effectively from ideation, design and manufacture through service and disposal.

Lindström uses a web based application called Ynique PLM for master of product in-formation. The application is designed especially for fashion, apparel and retail industries. It is suitable for big and small companies, having up to 10 000 users and it can be integrated easily to other systems used in the industry. (YniquePLM, 2017)

PLM provides the procurement planner product related data as shown in Figure 28: released products and product hierarchies, finished goods, Lifecycle management status in product level, BOMs, Raw materials, Suppliers, Allowed Supplier information.

Figure 28 PLM information

For Prodem products that are manufactured in Lindströms' own factory in Latvia, information about capacity needed to produce one product in minutes in also included. This will also include Best seller products in the future. Still some part of products, such as sweaters and blouses, are still without BOLs. Most of the products used in production are set as 'active products.' But in some customer specific products which are only sold to a certain customer the product is set as a 'non active.'

4.3.7 ABSSolute/Solar

ABSSolute/Solar provides procurement planner data about customer orders, laundry stocks and volume in circulation. This includes historical demand data for rental products, open customer orders, user group information in user/product level, volume in circulation, laundry stocks and laundry stock reorder points.

ABSSolute is preferred to Powered in Prodem factory because garments are made ready to the end customer and they need more user-specific information already in the production. ABSSolute will replace Solar in all Lindström countries during 2018.

4.3.8 Rob-ex

Rob-ex is a production scheduler that can be used in discrete manufacturing, process manufacturing or project manufacturing. It generates a comprehensive graphic overview of production and it includes versatile and efficient tools for fast and efficient scheduling. (Rob-ex, 2017)

Prodem, the factory of Lindström, uses Rob-ex for scheduling production and taking resources into consideration.

4.4 Processes

In this chapter the processes linked to capacity planning are explained in more detail. First the processes of planning of demand and supply are explained, because these are the methods that lead to the plan of capacity available. Then the procurement process that uses the capacity planned is then described.

Flow charts are used for visualizing processes. The information about these processes are collected from swim charts and asking questions from people involved. The original swim charts for demand plan as well as stock and procurement plan also include timeline, personnel and software. The simplification was done to get a clearer idea of the process.

4.4.1 Lindström Management Model

In 2017 Lindström started a monthly planning cycle called Lindström Management Model, LMM. The purpose of the model is to make the current situation and future clear and more transparent. Every month business plans for the next 16 months in every business unit are formed. Also reviews on country, area, region and group level are created. The plans are then compared with vision targets. Possible gaps between plans and business development targets are identified. The process has six steps as shown in Figure 29 below, including business unit demand planning and business unit procurement and stock planning. (Vahtera, H.,2017)

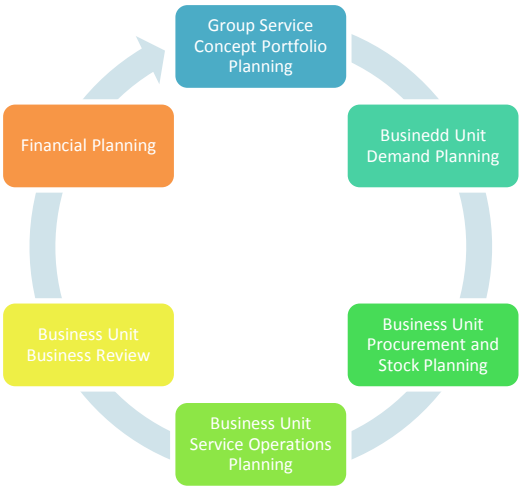

Figure 29 The monthly cycle of LMM

The monthly planning is used for gaining more knowledge of the execution of plans. The reviews have five main items: Action plan, Gaps, Assumptions, Opportunities and Vulnerabilities. The action plan transfers the forecasts to action that will help reach the goals and targets. This is the plan used for execution. Gaps are the difference between the current status and the future performance and goals. Assumptions are happenings that are considered true or certain without proof. They are used as a basis for the action plan and it is important that they are documented for further explanations.

Opportunities are positive business possibilities which are not yet quantified in the business plans. They are something which are wanted to be declared as a future opportunity and manage the opportunity to start to realize it. Vulnerabilities are the negative business possibility

which are not yet quantified in the business plans. It is a probability of an occurrence with negative impact that may be avoided through pre-emptive actions.

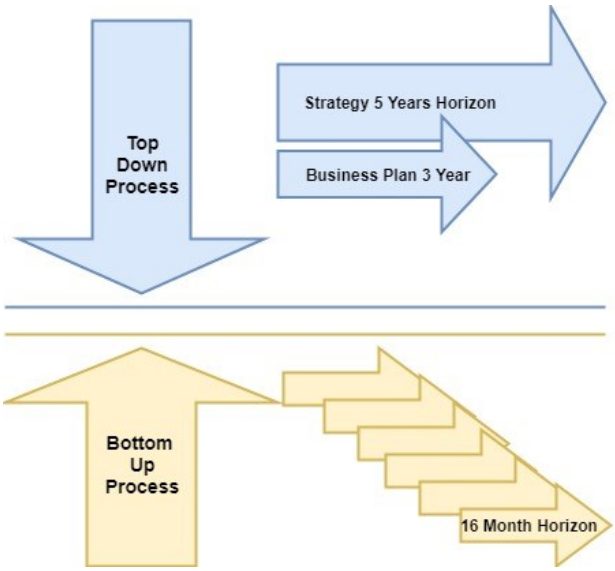

Figure 30 Lindström LMM (7 LMM Training)

Figure 30 shows how the LMM is a bottom up process that collect information with reviews and compare it to the Top down process of strategy and business plans.

4.4.2 Demand Plan

Demand is planned through reorder points in Powered and the information about projects. After a certain point in the inventory levels, a need for purchasing is launched. If the products are products that are not kept in stock, they will move to buyers who will make the necessary decisions. The reorders are planned with excel sheets and checked once in a couple of months. The Demand Planner has a spreadsheet with information of the demand in the last six months or so. This is done to spot possible trends. Information about seasonality is also used to manipulate the reorder point calculation if needed. Information is gathered about ongoing projects and also estimations for future additional orders from the business unit buyers. All the changes in reorder points are discussed with the Supply Chain Director. (Sihvola, 2018)

The demand forecasting process is presented in Figure 31. The demand process is where the demand is evaluated, planned and forecasted. It starts with updating information to a demand review.

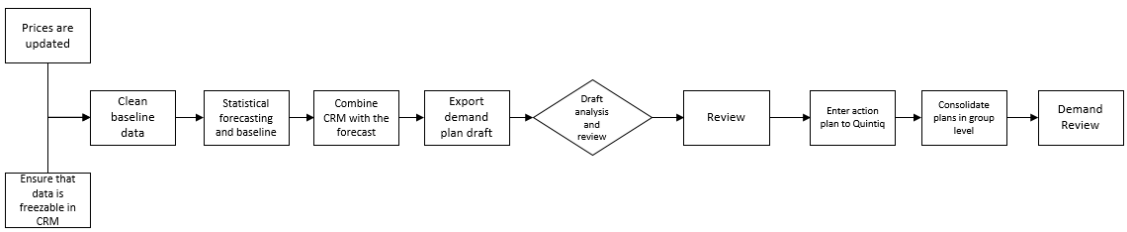

Figure 31 Flow chart for Demand Plan process

First the prices are checked by the Business Unit Manager (BUM) and if there is a need for an update, the Business Unit Buyer (BUB) updates the information to Quintiq Demand Planner. The Sales Manager ensures that the plan is feasible from CRM at the end of the month. At the first day of the month the Group Demand Planner cleans the baseline data in Quintiq Demand Planner. Big peaks that could be created by an error are removed. Then the statistical forecast with the baseline and information about product lifecycles is run. After that the forecast is combined with data from CRM and the end plan exported.

The BURs review the plan and it is uploaded to the LMM portal. Sales Managers review the plan by identifying its opportunities and vulnerabilities, analysing the previous round minutes and action analysis and update the plan based on the discoveries. Then the plan is validated, gaps are identified and action plans are made to close those gaps. The customer interface costs are then fed to the FPM system. The action plan is input to Quintiq by Business Unit Buyer. The Group Demand Planner consolidates the updated BU demand plans in group level and exports the consolidated forecast that is the Demand Re-view. (Demand plan swim chart, 2016)

4.4.3 Stock and Procurement plan

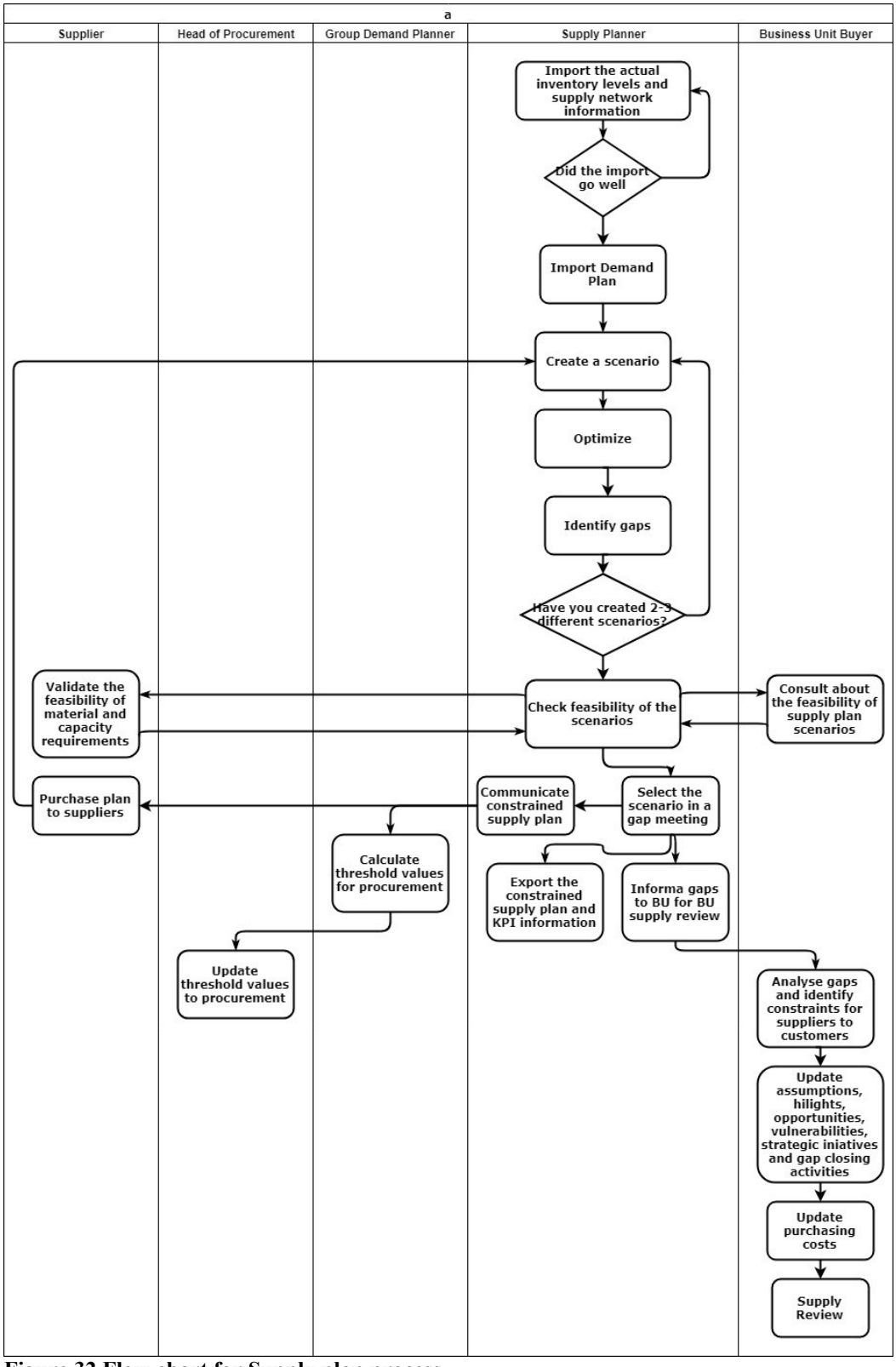

Figure 32 Flow chart for Supply plan process

Figure 32 illustrates the stock and procurement plan process. It starts with importing the actual inventory levels and supply network information from Powered, ABSSolute and Solar to Quintiq Macro Planner. If the import went well, the process continues by importing the

demand plan made with the Quintiq Demand Planner. With all the information in the system, the simulation of alternative scenarios starts. This is done by creating a scenario, optimizing it and identifying the gaps in the plan. Then the suppliers and BUBs are consulted of the different plans. The BUBs can communicate more about possibilities of gaps, such as large customer orders. The suppliers can validate the plan and possible changes in the material and capacity requirements. For example if there is more production capacity available.

Then the most optimal scenario is selected. The supply plan with KPI information is exported and gaps in the plan are informed to Business Units for the review. BUBs will then analyse these gaps and identify constraints from suppliers to customers. They correspondingly update the assumptions, highlights, opportunities and vulnerabilities. Based on these they create strategic initiatives and activities for closing the gaps. Then the BUBs update the purchasing prices and present their plan in the Supply Review.

The constrained supply plan is also communicated to the Group Demand Planner who uses it to calculate reorder point values for procurement. Then the Head of Procurements will update these threshold values to the purchasing system.

The supply plan is shared with the suppliers as well. This way they will have all the information needed for planning the production. The previous plan and changes made to the plan are needed when starting the new planning period.

4.4.4 Procurement process

The procurement is continuous process that is implemented daily. In the process the demand gathered from new products, projects and replacements are registered to different software and purchased from different vendors. Through these systems the information about the demand goes to the buyers who place the order to the supplier. If there is a need to check the capacity of the vendor, the Supply Planner is contacted personally by email or phone by the buyer. The process is presented in the process chart in Figure 33.

The purchasing process is done with a variety of tools and processes. The selection of the different purchasing routes is affected by the question if the ordered garments are to a new customer or new products to an old customer, re-order to old customers, or Prodem products.

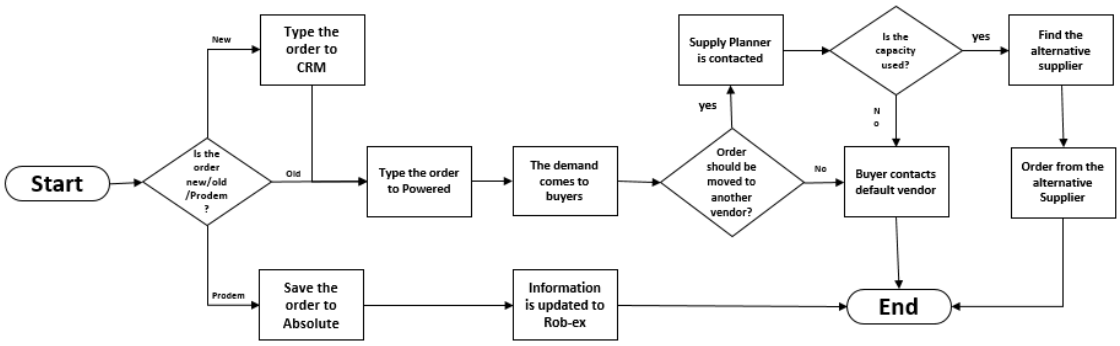

Figure 33 Procurement process

The garments needed are divided to three types: additional orders, replacement orders and projects. Additional orders are done by the customer by customer service or eLindström, the Lindström customer portal. They order for example more pieces of the collection selected for them because of for example new employees, such as summer workers. Replacement orders are just that, if garments are broken and cannot be fixed, the laundry orders more. Projects are large additional orders or new orders to new or old customers.

Re-order

Additional orders and replacement orders are handled in a similar way. After typing the additional orders to eLindström, the data is downloaded to ABSSolute every night. If the order is made by customer service, the order can be made straight to ABSSolute or eLindström. Replacement orders are typed straight to ABSSolute. ABSSolute is for now used mainly in Finland, but during the year 2018 it will replace the other system used called Solar. In Finland the information goes to a system called Ritil from ABSSolute. The system first checks if the laundry has those garments needed already in stock. This way the stock kept in the laundry stock is in effective use.

Then the system checks if laundry stocks nearby have the garments needed in stock. Every laundry in Finland has a defined selection of these friend laundry stocks that can be used for sharing stock. The friend laundry stock then signs the amount of pieces they have to offer. The garments are then sent by the daily transportation. If the other laundries does not have the amount of garments needed, an order is enrolled to Powered that orders the garments from the central warehouse or sent to Prodem via ABSSolute. The laundry does this checking on average once a day and up to one week forward.

Prodem product

If the product is listed as a Prodem product and the order comes from a Prodem country, the process is quite simple. Only certain Lindström countries order straight from Prodem factory. The order is inserted to ABSSolute or Solar by the sales person or subsidiary where it is updated to the production planning tool used by Prodem, Rob-ex. This information flow is presented in Figure 34.

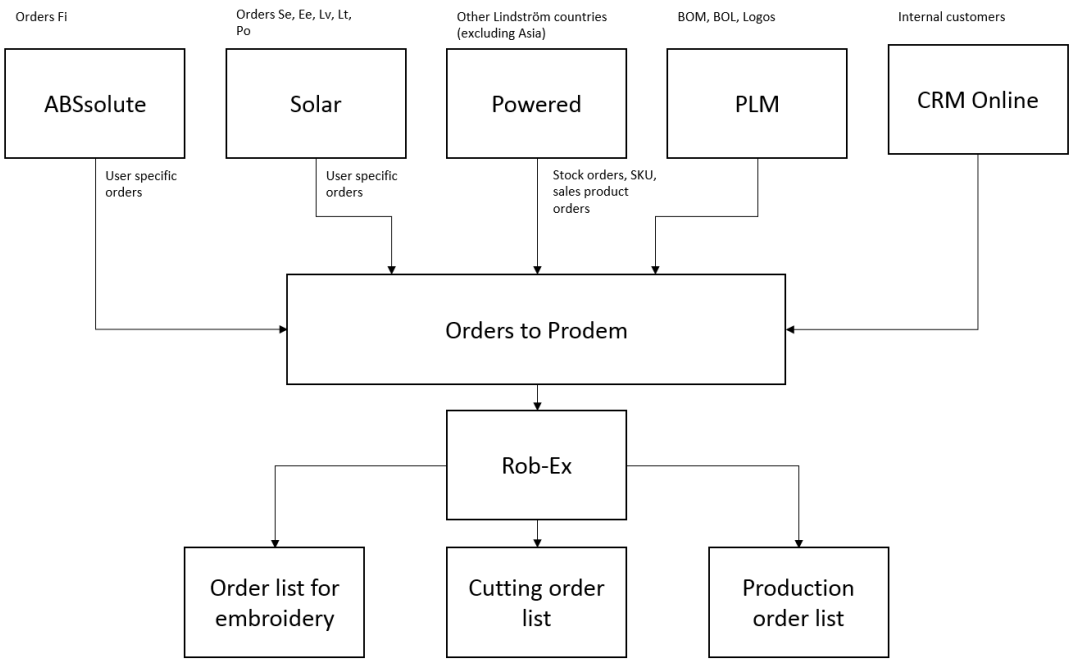

Figure 34 Orders to Prodem

Replacement order

For old known customers needing replacement garments, the orders are entered straight to Powered by the sales person or subsidiary. Through Powered the buyer will get the information of the demand. The orders are listed to a purchase list when the stock level goes below the re-order point. The purchase orders are divided to buyers based on the default suppliers. The orders emerge to the list by the order date that is calculated by Powered, it is the required delivery date minus the products lead time.

Purchasing

The buyer goes through the list one by one and checks the amounts ordered. The buyer makes the decision if the ordered quantity is smart to order. For example the buyer can leave the order open if the order is only one unit below the re-order point and the product is no in constant use. Next time the orders to that vendor are checked, the order will appear in the list again and if more of the same product has appeared, the order is proceeded. Then if all seems good, the buyer contacts the default supplier of that product and places the order.

The requested time of arrival is shared to the supplier that will confirm if the date is possible or give an alternative estimation for the arrival. The orders are handled in the order of arrival. If the buyer has a feeling that the manufacturing capacity of that supplier is full, the Supply Planner is contacted. The Supply Planner then checks the situation by checking the orders made to that supplier form Powered. If the situation appears under control, the Supply Planner informs the buyer to place the order to the default supplier. If it seems that there will be a problem, the alternative supplier listed to the product is found in Powered and buyer is instructed to direct the order to the other supplier. If this situation becomes recurrent, it is discussed if the default supplier should be changed to the alternative supplier.

Case support

In Figure 35 the process for customer projects is presented. New customers, new products to customers, change of models and large additional orders are first listed to CRM as Projects. Projects are handled by case support teams. Each team has a Project Manager and a Designer. Case support team works regionally, there is one team in India, one in China, one in Latvia, One in St. Petersburg, two in Hungary and 2,5 in Finland. When an order for additional garments is large enough, it is made into a project. This is done to prevent the sudden demand to the central warehouse, this way it is added to the forecasts and it is addressed earlier. Large order means that there are more than 50 pieces of one product or the total count of garments exceeds 100 pieces.

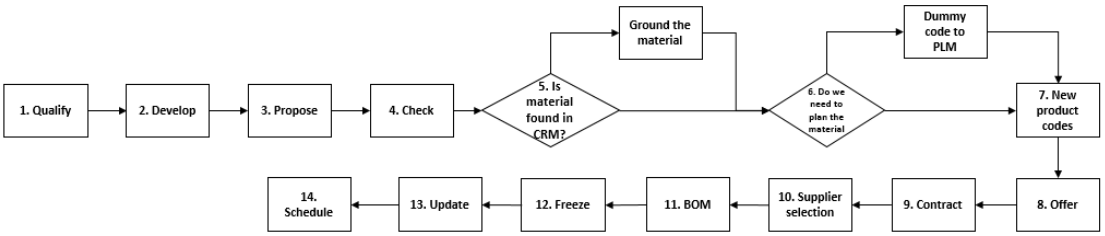

Figure 35 Process for new smart design products (GR Case Support)

The projects process for new products is shown in the flow chart above. The process starts with the Quality step. In this process step the Sales create a new opportunity to CRM and give it the first estimates about the case, meaning its size in pieces, timing in estimated delivery dates and closing time and probability for success.

The second step, Develop, is where sales is able to specify the size, timing and probability of the case with customer need and the necessary collections, materials and colours. Then a Project Manager is informed about the opportunity with customer information form (CIF) that holds more information about the customer and the case.

The third step, Propose, is about identifying sales cases for preparing offers. At this step the exact estimates about the size, timing and probability with the exact information about the proposed solution and the necessary collections, materials and colours. At this step the Project Manager receives information about the delivery schedule. Typically it takes from three to four proposes before the customer accepts the solution. This takes typically several weeks, but can last years. Next the Project Manager will check the information of the opportunity and CIF. Next the materials of the solution is checked. If the material has not been enrolled to system, it has to be grounded into PLM and CRM by the case support. If there is a need to start material planning because of a long time period between the need and offer, a dummy code for the material is created to PLM with BOM.

In step seven the product codes for new products are grounded to PLM and synchronised to CRM. Sales get an estimation of prices for products. Then Sales create an offer to CRM with the product level information. The Project manager is contacted again when sales estimate the probability of the offer to be more than 50 %. The Supply Planner then defines the supplier about the products. Case support will then add BOMs with main material, estimated

consumption, supplier and other mandatory information about the products to PLM so that the information can be used in supply planning. The last day of the month, the CRM and PLM data is frozen and integrated to Quintiq the next day. The Project Manager and Business Unit Buyer have a meeting to check what should be included in the demand forecast. The second to last step the Project Manager monitors the case to see that all the information is updated. The last step is when the contract is signed.

After the contract is signed the probability comes 100%. After the agreement is made, the procurement of the product can start. In this phase the manufacturers for the products are chosen, purchase prices are agreed on with the manufacturer and schedule made. After this, the fitting of products are done, and only after fitting, all the size information and alterations are known. This is when the projects is moved to purchase orders and handled like any order.

When the project comes to the point where the suppliers are selected, the project manager goes through the order with the sales person and creates a preliminary schedule. Then the selection of suppliers is made with the supply manager and production potential is prepared. When the products are set and the contract is signed, the fitting information is collected from the customer and sent to the project manager. Then a launch meeting is organized where the whole list is examined with the project manager, sales person, supply manager and logistics coordinators. In the meeting it is decided who should place the purchase order and when the product should be available. For central warehouses it will be the logistic coordinators who enrol it to Powered, for products ordered from Prodem it will be the subsidiaries placing the orders directly.

In pre-order products, the supplier counts the material required to manufacture the garments. In circumstances where Lindström buys the fabrics, the demand is communicated to Lindström buyers by the vendors. There are also products like knitted wear whose lead time includes the procurement of needed materials. Only materials stated in BOM are purchased based on forecasts. All other products are linked to orders.

For now, delivery projects are not used internationally so the customer projects in subsidiaries are often processed as small additional orders and not scheduled separately.

4.4.5 Capacity Planning

The contracts of the manufacturing capacity has been agreed with with some of the suppliers. The contract covers a number of garments manufactured with a certain supplier for a certain timeline. Suppliers are expected to inform about the capacity they have reserved and the material statuses. The information is gathered once a month.

At the moment there is no official process for capacity planning. The buyers have some kind of idea of how full the capacity of a vendor in a time period is. If they notice the capacity is used, they contact the Supply Planner by email of a phone call who can check the open orders form Powered or act based on gut feeling and knowledge of alternative vendors. If it is decided that the vendor is booked full, the order is directed to an alternative supplier and if the problem is recurrent, the default supplier for products can be changed to Powered.

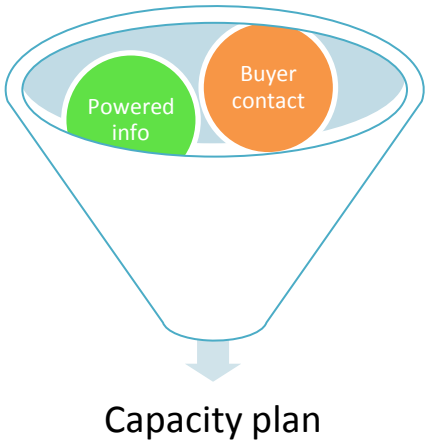

Figure 36 Capacity planning in current state

Material needed for orders is calculated manually using excel as a tool. There is no way to really know the current capacity of a supplier, only estimations.

4.4.6 Difficulties

Problems occur when the usage of the capacity is detected only when the problem has occurred. At that point it is already too late to respond to changes in the plan. This causes that a lot of time and energy goes to putting out fires when no one is aware the situation in higher level.

The forecasts use statistical forecast of additional and replacement orders. The statistics are first cleared of the peaks in demand to get a more general forecast. When these peaks happen, the plans are not prepared. Because the peaks in demand are only noticed when the capacity is full, there is no time to react. Only then some of the products are ordered from another vendor. The supplier might not be able to manufacture the products on time, or the garments are ordered form China with air freight that is more expensive.

Projects also cause variation in demand. Many times information about projects does not reach the Supply Planner on time. This causes that she does not have enough time to look into different options and schedules. The Supply Planner has to make supplier decisions based on a gut feeling. There is no way to know, how much will be ordered from a supplier at a particular time, it is even very hard to get the information how much has been ordered and how much capacity it eats. There is also a possibility that the project schedule prolongs so the selection of supplier for products is not optimal.

Since there will be peaks in demand and unpredictable projects, it is important that there is a tool for following the usage of capacity. This way the reaction to the risk could be more preventive. Orders could be redirected to alternative vendors before the whole capacity is used. This needs to be done often enough for more accurate idea of the situation.

In situations where alterations are made to the plan, there needs to be a way to be a way to review the con-sequences of the modifications made. Without a properly functioning tool it is impossible to understand all the effects to the entire plan. For example, if a supplier has fabric and manufacturing capacity now, it does not mean it is all available when needed. There might be a large order tomorrow that needs all that fabric and if it is used even partially the plan needs to be reformed again. All this changing goes to a vicious cycle and no one knows where it is heading.

5 Discussion

The processes described in this report are all working towards the same goal, but the current demand and plans made do not meet. There is a need for a procedure that will work as a link between these processes. In it the capacities planned and agreed on with suppliers are compared to existing purchase orders. This way Lindström could make most of the plans and capacities existing without having to use valuable Supply Planner time for manual calculations and information searching.

The capacity planning is like production planning in Lindströms' case. Most of the production is outsourced, but the higher level planning is the same. At the end of the planning hierarchy is not the production plan, but the purchase plan.

Transparency, control and planning is wanted from the solution. The idea is to have a process and a tool to prevent overuse of capacity and get a more detailed plan.

5.1 The process

The whole planning process is shown in the Figure 37 below. The link between the aggregate production plan and purchase plan has been added. At the beginning is the demand plan process as explained earlier. Next comes the Stock and Procurement process that makes the monthly procurement plan. In this Figure is the aggregate production planning. Mid-term plan uses the aggregate production plan as a base using the schedule for forecasted additional and replacement orders per supplier as well as planned suppliers for customer projects. The plan also needs information about the suppliers, like the supplier maximum and minimum capacities that are collected monthly. This includes the production capacity and the materials available. A lot of different information is needed from the product. This means the BOMs, BOLs, the alternative suppliers for products. The information of orders for planning include the purchase orders and projects.

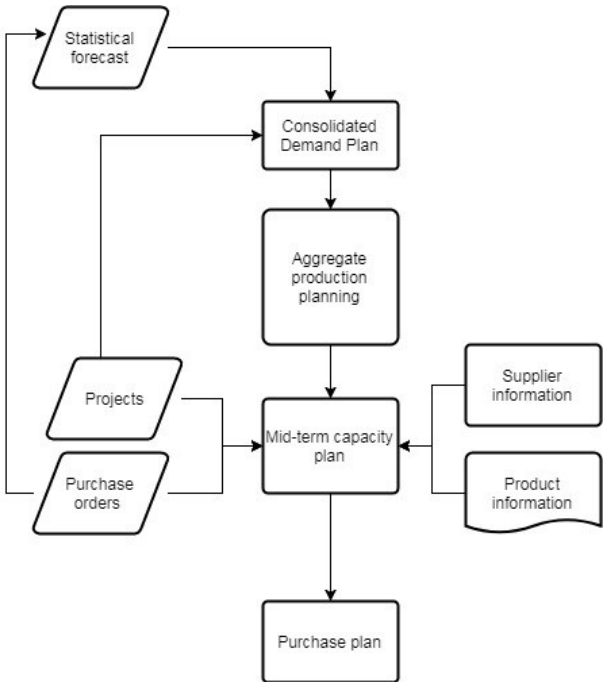

Figure 37 Lindström Procurement planning Process chart

The timeline is very critical when planning the process. This could be that the software is run and the plan updated weekly and when needed, more often than more seldom. If the software runs automatically it could be even real-time. If the plan is used only to follow capacity utilisation, once a week of less often could work. Due to this all the information in the plan are outdates and cannot be used for anticipatory scheduling. If the project is used mainly for project planning, it has to be updated after every project comes to that phase like in Figure 38. Additional and replacement orders can be updated more seldom, since they are not expected to vary much from the forecast.

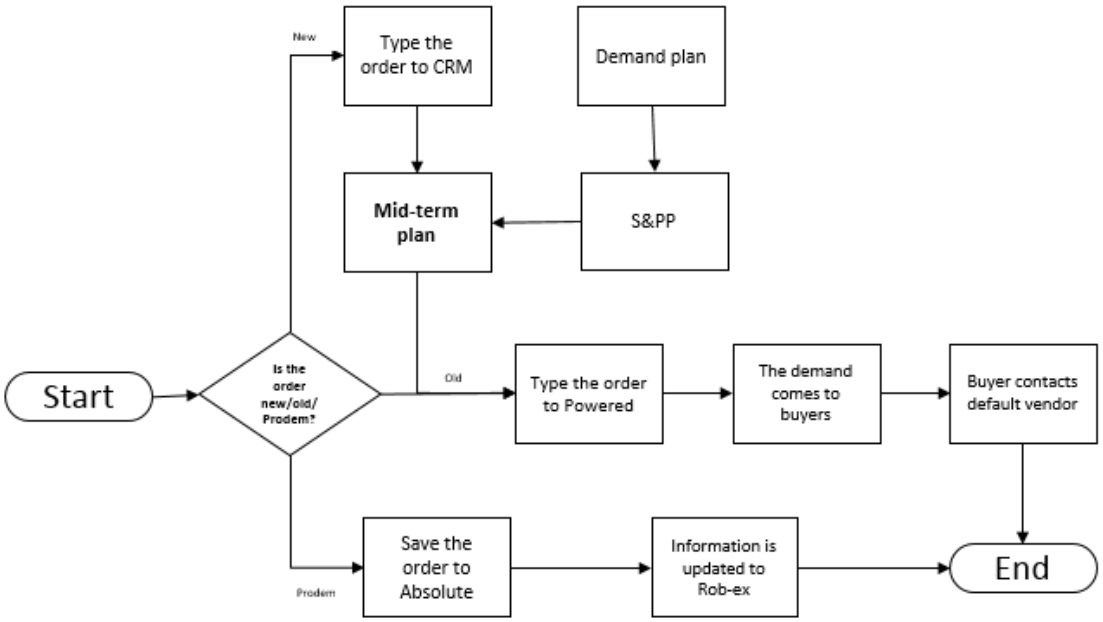

Figure 38 Mid-term plans place in the procurement process

The schedule needs to be updated more often if it is used for organizing orders. For ex-ample if the plan is updated every evening, the purchase orders of the following day could be made based on it. The Sourcing Director estimates that this one day delay would not make a dif-ference, actually one of the buyers states that the orders from the same day do not appear on the purchase plan unless the same products are already being ordered If the schedule could be made with all the purchase orders, the most optimal solution could be found and all re-sources could be used in a sensible way.

5.2 Tool

The process sets the qualifications for the system. The selected system should be able to fulfil these qualifications.

The input for the plan is presented in Figure 39. Integration to Lindström systems will be done through new integration ecosystem. The base for the mid-term plan comes from the long-term plan made with Quintiq. This includes the possibilities for both Demand Plan and the Supply Plan. The Demand Planner uses historical statistical data about orders and CRM estimations of projects to aggregate a total forecast of demand. The Macro Planner uses this plan and information about supply available to conduct an optimized supply plan. The fore-cast unit for 0-4 months is in products.

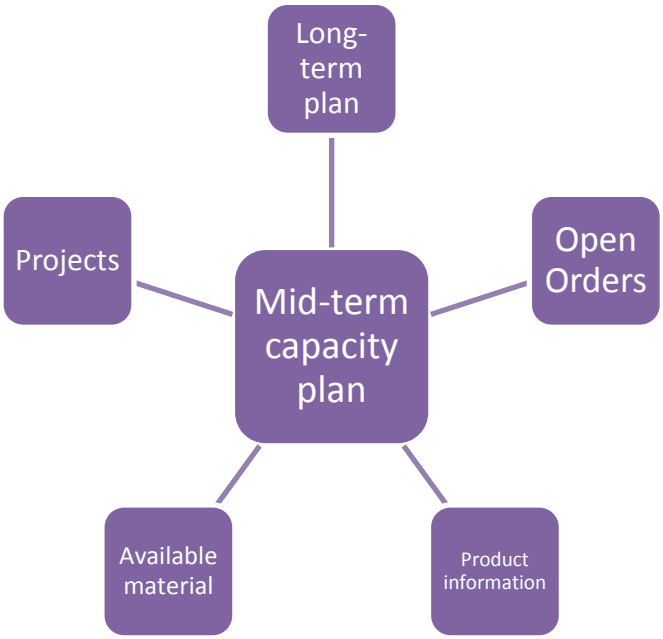

Figure 39 Information needed for the mid-term plan

The confirmed orders are needed to follow the used and fixed capacity. This information will come to Prodem separately and from Powered for other suppliers. The product infor-mation will come from the master production system PLM. In PLM the products have both BOLs and BOMs. The material and supplier capacity is of course needed for the planning. This information is gathered monthly from the suppliers to be used in long-term planning.

The information of customer orders comes from CRM where the projects are controlled. The Delivery Projects have the information necessary. Delivery projects are projects that are advanced to scheduling. At the primary state of the project, the information such as the amounts ordered and due date come of the project. Dynamics CRM short term supply plan will have new features added to the system with the new project. These features include more information about the order, such as specific products and of the progress of the project.

5.2.1 Functions

The requirements for the system were divided into three parts: capacity tracking, projects scheduling and execution to purchasing. Capacity tracking includes tracking the used capacity. This is done so that the capacity usage can be monitored. Also changes can be made to the planned capacity. The forecasted capacity can be moved between alternative suppliers and changes to the values planned made. Material availability is tracked in the system.

Project scheduling is a central part of the planning. It is important to keep up with the development of customer projects. The tool should show the development, or the lack of it. The tool used should help plan for suppliers for these projects, including new products and existing products. The planned projects that have not proceeded to purchasing yet, can be moved between alternative suppliers and on the timeline. This finite capacity planning should consider material stocks when planning.

Another important feature of the tool is the way the plan can be shared. There are different roles needing different kind of information. As the process chart shows, the in-formation needs to be shared to purchasing and projects.

Capacity Tracking

The mid-term supply plan should trace capacity usage in weekly bases. This is done by comparing the capacity usage to the maximum capacity available. This can only be done after the acquisition time. The system should also keep track of the material availability.
This should be done to every supplier separately. It should also show information of arriving orders and warehouse capacity.

Input for this process consists of the supplier capacity, open orders, arriving orders and warehouse capacity. The maximum capacity of a supplier is gathered from the supplier and is used in the long term plan. Material available for the supplier is also needed. Used capacity is also referred as open orders or confirmed orders. The system also uses the forecast of capacity usage and other available supply as arriving orders and central warehouse capacity as input.

The output should consists of a visual graph of the capacity used per week per supplier and for all suppliers. Also information of the orders included in the open orders and Available-to-Promise should be found in the output.

The tricky part is to compare the right information and check that there are no duplicates in projects scheduling. If the project is already purchased, it should not be in scheduling any more. One problem has been how to use a right format of the forecast smartly.

Project Scheduling

This is the process used for scheduling projects. The plan should show important dates to projects and try to keep up with the planned schedule. This should be finite capacity planning considering material requirements.

The input needed for this process are: The capacity available per a supplier, Forecasted maintenance orders, CRM Delivery Projects, material stock and product information.

The output is a plan that shows when certain information of a project is needed and when it can be purchased. It can also be used to plan suppliers for new products.

The challenges are to check if projects are ready for the purchasing. There is a possibility that some information is still missing and that the project needs to be moved to a certain distance.

Also it has to be checked that there are no duplicates. If a project has been moved forward, it should not be scheduled again. The plan has to consider material stocks of suppliers as constraints. This information is updated only once a month to the long term plan. After this the availability needs to be calculated using BOMs of the products ordered and planned to order.

Sharing the plan

The Mid-term capacity plan needs to be shared with operative buyers, suppliers and other parties involved. These parties are presented in the Figure 40 with the different roles involved. The information and schedule of the project must be shared with buyers that can make the necessary purchase orders and requisitions. Information about the project schedule must be shared to the project managers.

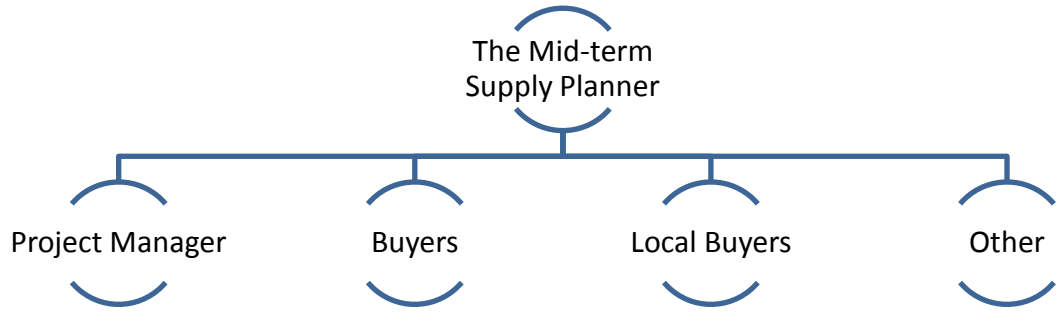

Figure 40 The plan is shared to

The challenge is to make the system view so that the stakeholders find the information they need easily. The solution should be flexible and the views customisable. Also there should be an option to use different roles. The trick is to find the necessary information from the whole plan to each role.

There is a possibility for sharing the plan outside the system, but this brings risks for misunderstandings. For example O365 that is used by Lindström word wide, provides online workgroups and platforms.

5.2.2 Qualities

There are many different qualities of the process and the tool to consider. These decisions that are made in the process, should be enhanced quality in the tool.

User means the person who updates the plan. This could be the Supply Planner as the only person who has the authority to alter the plan. It could also be anyone who uses the plan. The most modern way is to have the plan run automatically. Supply Planner is for now the only one with the knowledge to do capacity planning, but her workload is large. If there is only one person making the plans, it has to be the supplier planner. Only one person manipulation plans make them more consistent and there is no obscurity on who is making plans. Hopefully with efficient capacity planning that workload will ease on the Supply Planner when there is no need to extinguish fires that have already started.

The Supply Planner will always be needed to some point but if the process is heavy, the best way would be to share the workload. If the plan could be run and verified by some people, the knowledge about the process and its phases get more transparent and for example in case of illness, someone could keep up. Automatically running plan sounds tempting but might not be the best option. It is hard to gets the program running smoothly and still almost every time the plan needs manual manipulation. This last option would free capacity from the Supply Planner and everyone involved to other necessary actions.

Visibility means access to the plan without being able to alter it. The options are that everybody, only the selected ones or just the Supply Planner. At the moment capacity planning only affects the Supply Planner, the buyers and projects. If only the Supply Planner has access to the plan, the process of procurement will stay almost the same. This causes that the buyer will have to contact the Supply Planner every time an issue arises, who will make the decisions based on the plan and get back to the buyer.

This way a lot of extra time and energy goes to exchange of information and waiting. Of course if the process mainly follows the usage of capacity and the selection of project suppliers without making any changes to the existing purchase orders, the Supply Planner might be the only one using the process. However, if there is a function that makes changes to orders and schedules, it would be good to give access to the buyers also. There is a possibility that other stakeholders are interested in the plan. If there are many people that want the access, a web solution that is available to everyone in the organization could be good. This way no extra time and effort goes to getting the login access to the software or making reports about the existing plan. It all depends on how easy it is to delimit the personnel involved.

For the scheduling, one of the main things, is the sequencing. This could be First-in-first-out, Earliest due date or something different. The most common one is a combination of different strategies with coefficients and restrictions. It has been clear from the beginning of this process that this tool should be used for capacity planning that schedules the orders based on time and material inventory. The end result for dispatching rule will be a mixture of rules. At least one physical constraint will limit the plan, the material. How much each supplier has material in stock and when orders should arrive affect the selection of suppliers and the schedule.

EDD is a popular way to plan capacity but it can cause gaps in the plan that need to be filled in another way. If the sales orders' expected delivery date is after a year, it only takes capacity closer to that date. Powered uses this method to release orders for the purchase list. In case of a typo, the orders will not be ordered until the date comes, for example the year 3000. If sales personnel are trusted to enrol orders in the order in which there are needed, or in quite even pace, and most of the customers are internal customers, it might not be a crime to produce the garments beforehand and use FIFO as the rule. This would make sure that the capacity is used to the fullest every week. For example that the orders from Madagascar are always fully fulfilled to the maximum capacity by selecting orders that have delivery late. This way there is more room at the end of the schedule.

5.2.3 The appearance

The tool should gather the information about the capacity of each supplier. The tool is also used to move capacity between suppliers and within reasonable time scale. The system should have at least two different views, one for suppliers and one for a supplier. This is because projects could be moved between suppliers and within a timeline.

The Figure 41 below shows an example of how the view should look like. Suppliers are listed in rows like in the example and the horizontal axis is time and capacity usage is shown in the bars. The whole axis will show all the weeks in the plan and within a week there should be bars showing the open orders, projects planned, forecasted orders and available capacity.

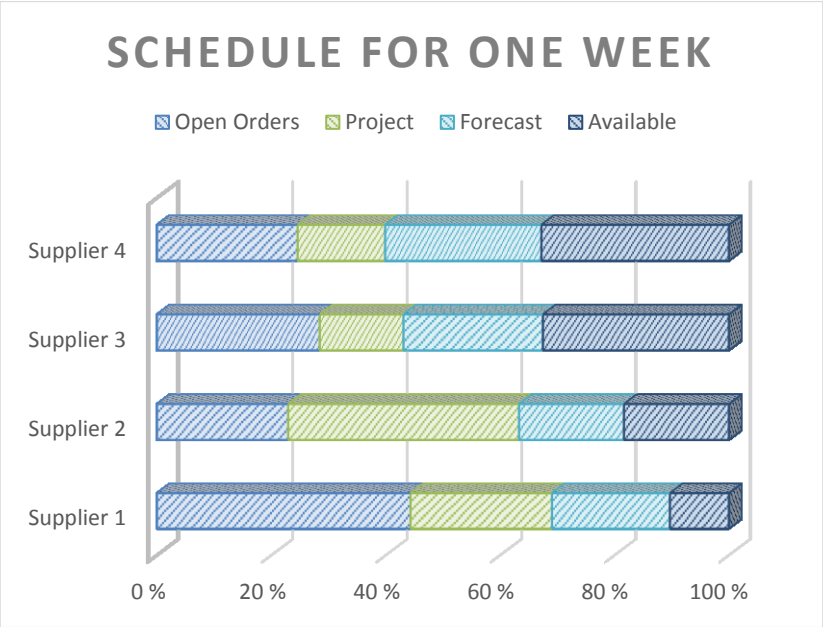

Figure 41 Schedule example for multiple suppliers

When the Supply Planned starts to look for available capacity within the suppliers, the visualisation helps to choose new supplier for a new product that has not been set yet. Also there is the possibility to move some of the orders earlier if possible. Within the acquisition time all the forecasts will be perished to available capacity.

For each supplier the tool should be able to show information about the capacity promised, capacity used and capacity planned. The information about capacity used will be gathered from suppliers for the long term plans. The capacity used means that orders that are already confirmed by the supplier. The planned capacity usage comes from the statistical forecasts of additional and replacement orders and the planned suppliers for projects. For an accurate plan, the made orders should show the information about the portion of orders to a project. This way only the additional and replacement orders eat the forecast. The plan will look different for suppliers in Europe and suppliers far away, such as China and Madagascar.

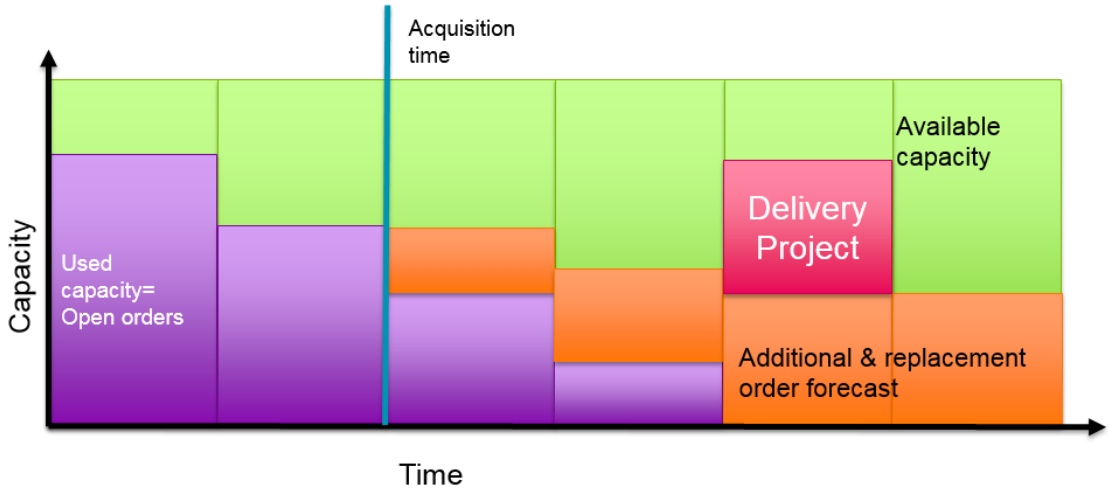

Figure 42 European supplier capacity

For most of the suppliers it will show as in Figure 42 above. Up till the acquisition time the plan includes only capacity available and used capacity. The available capacity derives from the information gathered from the suppliers every month. As the maximum capacity is not fixed but more negotiable, the amount varies.

The used capacity are the orders that have been confirmed by the supplier. These orders should not be altered because they are already set, not impossible but not the optimal option. The orange boxes are the forecasts of additional and replacement orders. These forecasts are fed by the made orders. Since the tool is made to manage capacity and help to plan projects, the forecasts reserve capacity until the point of acquisition time. Still no orders are made based on these forecasts. This means that up until that moment, the Supply Planner must have the option to move the forecasted capacity and replace it with Delivery projects.

Overseas suppliers that are located in China or Madagascar have long lead times. This means that the purchase plan is more based on the forecasts. This does not mean that only additional and replacement orders are ordered from overseas, also large projects are directed to these suppliers. The tool per supplier should look something like in the Figure 43 below.

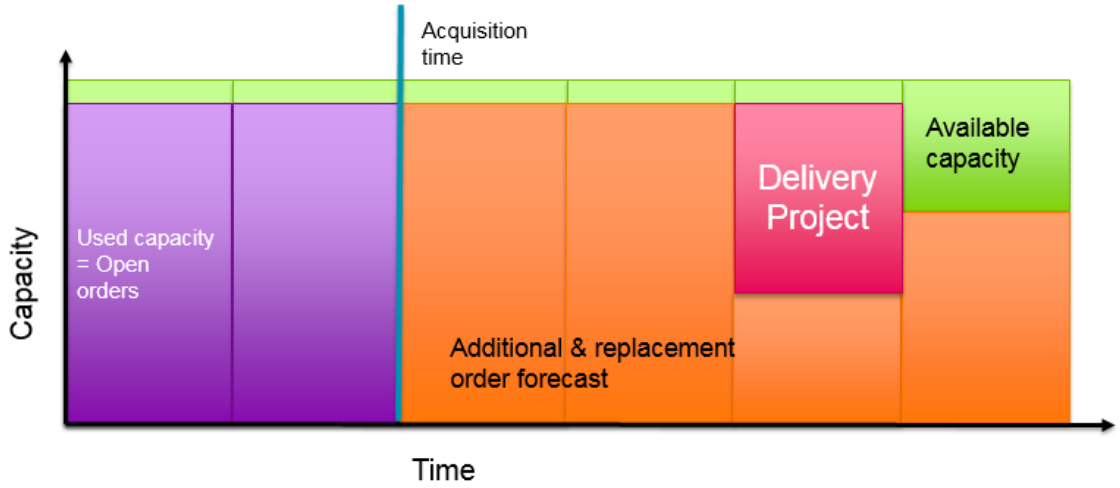

Figure 43 Overseas supplier capacity plan

In the future, the overseas purchasing will rely more and more on forecasts. All orders are either forecasted orders or large delivery orders. The biggest difference to current state is that there are only two sources to the used capacity, forecasts and projects. Because the forecasts are made monthly, there is no reason to make orders daily, unless there is a project that is scheduled to be ordered that week. Since the schedule is only done once a week, it should be quite clear what is ordered that week after the update of the plan. Naturally, exceptions will occur. There is an option to order garments from these suppliers with air freight, which means that there are two different acquisition times. Transportation by air is more expensive so it is not the optimal solution when selecting suppliers, but it is feasible.

There are some features that should be able to be changed manually. Therefore some values can be changed by the Supply Planner. These changes will make a change to the restrictions of the plan. This soft information is altering and negotiable. An example of this is the supplier capacity. As the maximum capacity is not unambiguous. It can be given in pieces of clothing or in minutes. Also some of the products are directed to a separate production line.

Many times the capacity can be negotiated with the supplier. So even though the maximum capacity is the limit for scheduling, the Supply Planner can go over the limit.

The overseas suppliers have two ways for transportation: air freight and sea freight. There is a different transportation time and expenses. The first option should be the sea freight, but from approval of the Supply Planner, orders could be moved to the fast track. This is an exceptional action and not a norm.

There are still some things causing abnormalities between the plan and reality. For now the buyers are making a lot of choices about what to order. If the amount below re-order point is very small, the order is not made. Also information about batch sizes between suppliers are not known, so the plan only considers forecasts and made orders.

6 Results

6.1 Process

The new tool used for the mid-term capacity planning process uses information from the one month supply plan, CRM short term supply plan and confirmed orders. The supply plan is made by the Supply Planner, this is the plan made with Quintiq Macro planner. The information gathered from this plan is the capacity planned for the supplier and the amounts of additional and replacement orders. CRM short term supply plan has the information of projects before the information is enrolled to Powered and converted to purchase orders. The project might not yet have all the information needed for purchasing, like fitting information yet. After all information needed is gathered to CRM short term supply plan, the project is ready for purchasing. The information needed from CRM are the amounts ordered and the delivery time. Open orders are gathered from two different sources, for Prodem and for other suppliers. Open orders for Prodem are gathered from ABSSolute, Rob-ex or the new integration base. For other suppliers, the system used for open orders is Powered.

The new tool used for this process uses information from the one month supply plan, CRM short term supply plan and confirmed orders. The long term plan is made using Quintiq. The information gathered from this plan is the capacity planned for the supplier and the planned additional and replacement orders. It would seem that the best way for this is the information in Macro Planner before the optimization. In this phase the MP compares the demand plan per stocking point to the products actual inventory in that location. The long term plan comes from the box number 1 in Figure 44.

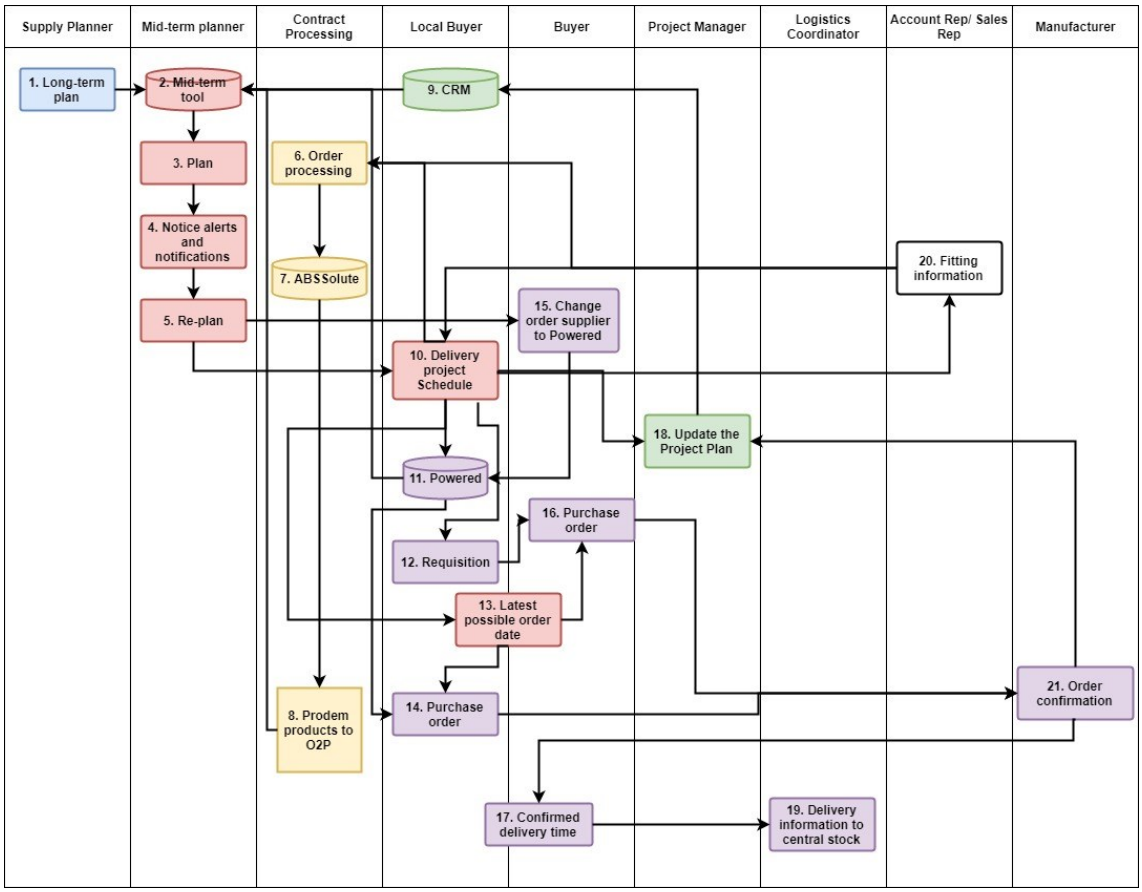

Figure 44 Process for mid-term planning

CRM short term supply plan, in box number 9, has the information of projects before the information is enrolled to Powered and made to purchase orders. The project might not yet have all the information, like fitting information. After all information needed for purchasing information is gathered to CRM short term supply plan, the project is ready for purchasing. The information needed from CRM is the planned amounts, delivery time and the progress of the project. Information about whether the purchase orders to a certain delivery project have been made should also be found in CRM with fitting information.

Open orders are gathered from two different sources, from Prodem and from other suppliers. Open orders for Prodem are gathered from ABSSolute, Rob-ex or the new integration base, in this Figure it is the box number 8 Prodem products to O2P. For other suppliers, the system used for open orders is Powered. Also the supply as stock levels of central warehouse and on-the-way stock comes from Powered. Powered is the box number 11 in Figure 44.

In box 2 all this information is imported to this new mid-term planning tool. The tool is used to create a weekly plan, this is done in box number 3. Regularly, the plan might need some adjustments by manually manipulating it. This could be done by following alerts and notifications but also by using other information the planner has. These steps are shown in boxes 4 and 5. This is a circle and the changes will be made until the plan looks feasible. The Mid-term planner then releases the plan to local buyers as a delivery project schedule.

In order for the plan to make room for the projects, other orders need to be moved. Since there are only the forecasts and the open orders, the forecasts are the changeable objects. If the capacity is full, some of the planned capacity for product is moved to another suitable supplier. If changes are made to suppliers for products in the plan, the buyer changes the supplier of the product order to Powered temporarily. This is done in step 15.

In step 10, the plan for customer projects is released as Delivery Project Schedule. Based on the plan, the local buyer makes the sales order to Powered in step 11. These third party products purchase orders are made by the local buyer in Powered and the supplier makes the order confirmation to the same system.

Because there is no stock kept for customer projects, only for small additional orders and replacement orders, there is a need for a separate requisition even if the product is kept in stock. In step 12 the local buyer will place the requisition to Powered to the planned supplier based on the schedule. The order will continue as an ordinary purchase order to the right buyers in step 16. Then the order will be confirmed by the manufacturer in step 21.

The confirmed date will be used by the Local Buyer and Buyer in step 17 to check for inconsistences. The Logistic coordinator will use the confirmation for delivery information to central stock in step 19. The Project manager updates the project plan if the manufacturer's response differs from the plan. Prodem products go through the order processing and ABSSolute. These are the steps 6,7 and 8.

The Delivery Project schedule will also affect the project plant and set a timetable for fitting and order processing in ABSSolute. When the account representatives or sales representatives have the fitting information, it will be enrolled to ABSSolute and to the delivery project schedule that the project is ready to move forward. The information about open orders will come to the system from Powered. This is the step 20.

The different colours in the process chart represent different systems. Blue is Quintiq, green is Microsoft CRM, purple Powered and yellow for ABSSolute. Red colour is in the process steps where the new mid-term planning tool is used.

At the start the plan will be made every Monday. This is to get a better view of the capacity utilization. To keep the time used for planning in reasonable scale, it was decided to start with once a week and if needed, the pace will be increased or decreased. Monday was chosen because the week starts from Monday and this way to start the week with a new plan.

6.2 Tool

The Mid-term planning process needs a tool, a system that helps to create the plan.

6.2.1 Alternative systems

At the beginning of this project it was discussed that the software used for capacity planning could be one of the software already used at Lindström. There are at least three alternatives that offer solutions for planning. One is D365 that has a module for finite capacity planning. Quintiq is already used for the long-term planning and could be expanded to mid-term also. Rob-ex is s a scheduling software that is used for Prodem at the moment. All options are available. Although, this would means starting from the beginning, since there is no one in

the process who would know the program. This is a risk, because there are no guarantees that the system will operate and that integration will work. All integrations have to be built from scratch and the users have to learn to use this new system.

D365 Master Planning

Microsoft Dynamics 365 has a MPS module which includes finite capacity planning. The plan can be seen in Figure 45. Lindström already uses Microsoft CRM tool that works well with web browser. Since CRM delivery projects is the tool used for handling projects, the information is already included in the system. There is a D365 project coming, where it will supersede the existing purchasing systems. The disadvantages are that the scheduling system is not familiar to the Supply Planner, or anyone else in Lindström. For now, it does not include information about purchase orders, forecasts, supplier information or product information.

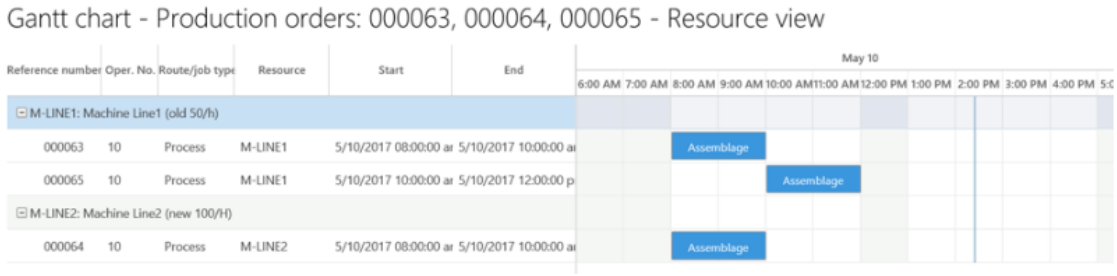

Figure 45 D365 Plan (Microsoft, 2017)

D365 Master planning allows companies to determine and balance the future need for raw materials and capacity to meet company goals. It does this by considering what raw materials and capacities are currently available and what are required for production. The Master planning uses this information to calculate the requirements and to generate planned orders.

Master scheduling plans typically involve the short term, which can be anywhere from one week to six months. The Master planning module determines the supply, like materials, and capacity resource needs that will meet current demand in the net requirements.
The following learning map shows the major concepts and tasks that make up the framework of the Master planning module.

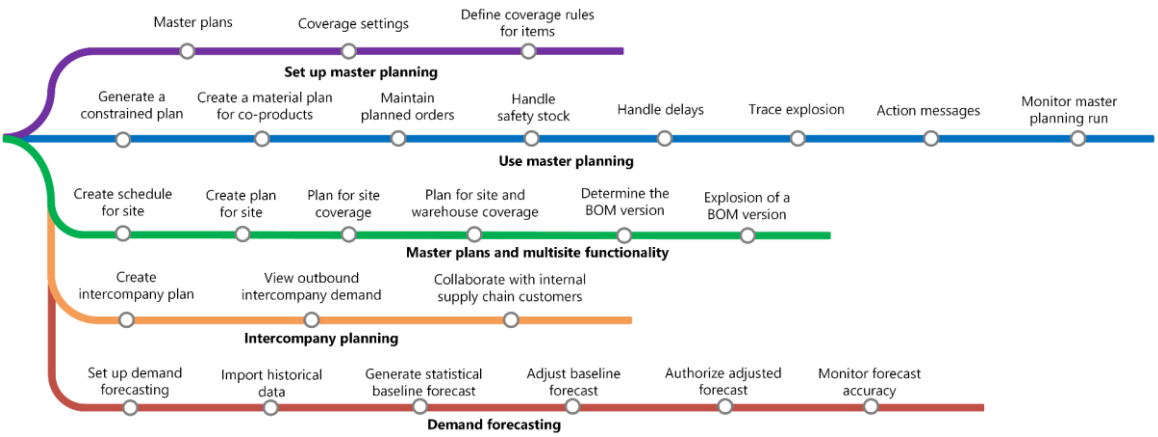

Figure 46 The framework of the Master planning (Microsoft, 2018)

6.2.1.1 Quintiq

Quintiq Company Planner is MPS system that is a separate module that works seamlessly with other Quintiq modules. It helps with tactical decisions such as whether new orders can be accepted, reacting to changes, analysing problems and suggestinging changes. The Figure 47 below shows the All-in-one supply-order view in Quintiq Company Planner. (Quintiq Company Planner, 2018)

It does this by honouring the long-term commitments. The contractual commitments are considered when allocating production to prevent over-committing and double commitments. The system creates a plan that is feasible and flexible. The plan shows available capacities, complies with promised delivery dates and accommodates changes. The system supports continuous planning and optimization. It considers lead time logic at the supply-order level. (Quintiq Company Planner, 2018)

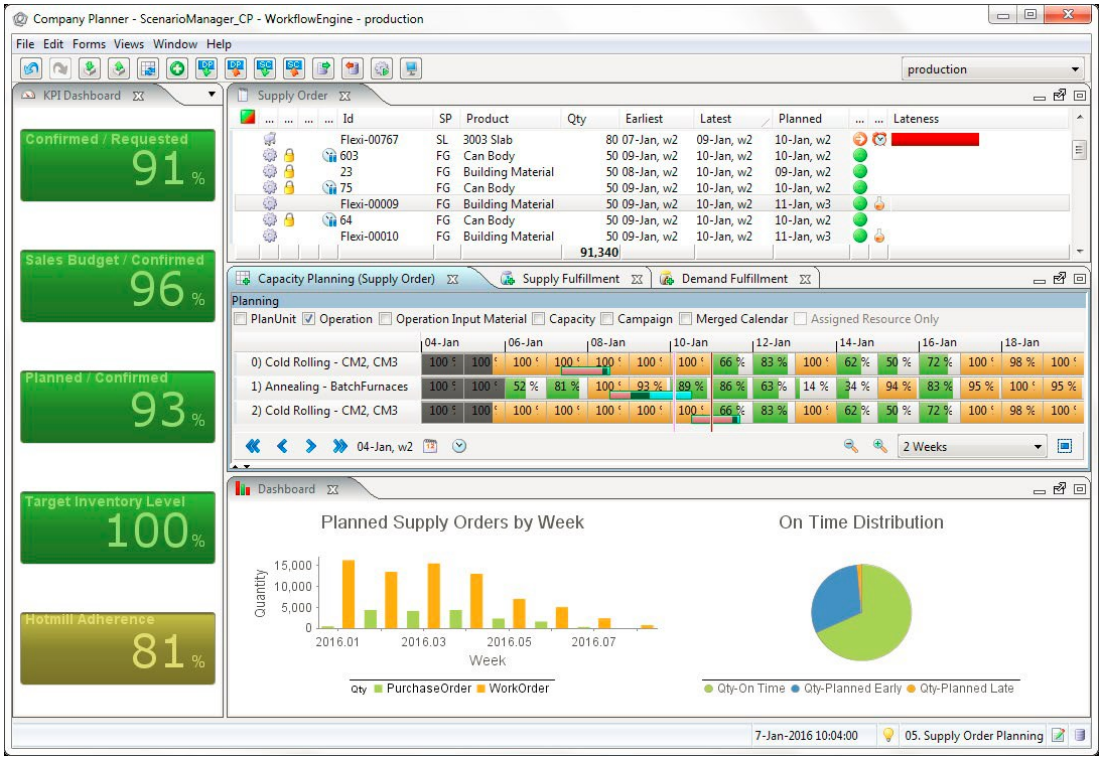

Figure 47 Quintiq Company Planner

The system manages bottleneck resources to facilitate the planners to reconcile and optimize the supply chain against actual capacity. Therefore orders can be fulfilled fully on time. It measures KPIs in real time so the impact of changes on different levels are displaying. The Company Planner can be used to optimize continuously, so that there is no halt caused by the update. The system balances inventory level so that the mixture of MTO and MTS inventory mix is balanced. By ensuring the adequate material supply the company Planner plans around material shortages by exploring different routing options. The system also alerts the planned if there is a risk at some point.

Quintiq Company Planner takes multiple factors into consideration to determine the accurate delivery dates for new orders. It ensures that the orders booked do not exceed the materials and resources available and that the capacity reserved to orders not placed is not allocated to others. The system leaves space for planners' judgement and intervention. It supports making manual changes to the plan for better tactical decisions. The user interface is designed to be flexible and easy to use.

Rob-ex

Rob-ex Scheduler is a standard software solution dedicated to production scheduling. The Scheduler provides a comprehensive, graphic overview of production and versatile and efficient tools for fast and flexible scheduling.

It is a simple and fast scheduling and re-scheduling tool that has full and immediate graphic overview of the implications of changes in production. The scheduling based on the various time horizons that are relevant in your particular production processes. It has immediate overview for answering questions regarding delivery times.

It is efficient tool for identifying and avoiding bottlenecks and for reducing lead time and the level of work in progress. It gives a total overview to address and solve problems in due time. If an order is going to be delayed the system gives an opportunity to notify customers immediately. All the information is available to provide a qualified and precise overview of the situation. The optimising tool helps to balance the workload on machines so that the use is ideal. There are clear markers for distinguishing between production to stock and customer orders, so that it is possible to identify and postpone production to stock and get rush orders processed first.

The system is designed to manage the dynamics and fluctuations that are natural factors in all production and supply chains. (Rob-ex, 2018)

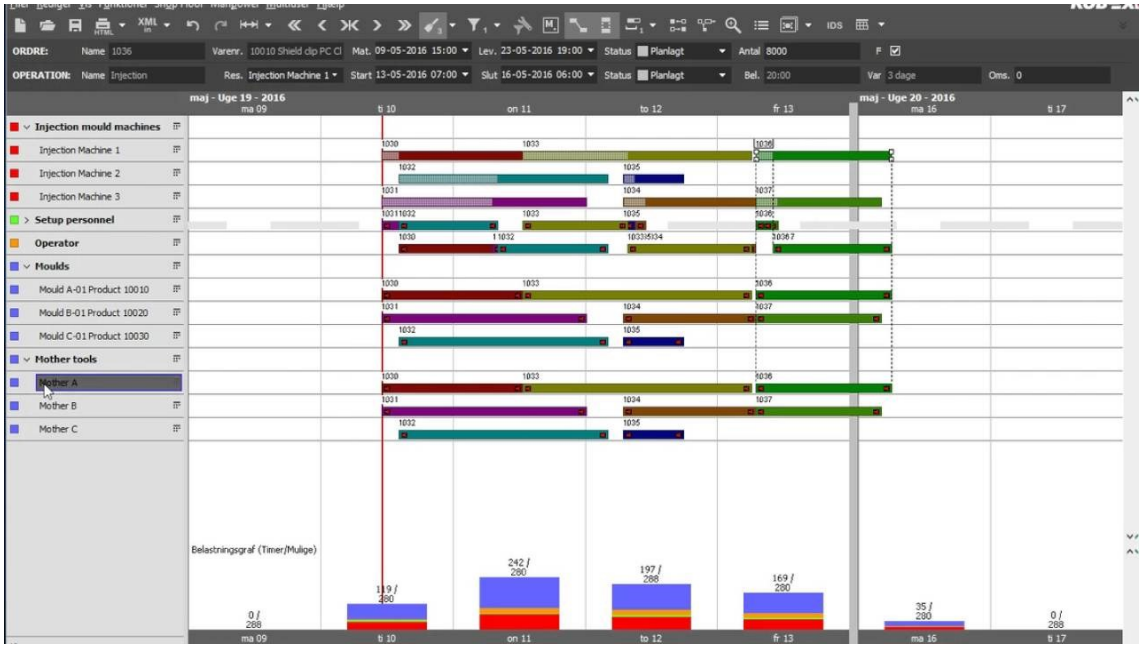

Figure 48 Rob-Ex Production Planning (Rob-ex, 2018)

IBM Planning Analytics

As the situation is what it is, one of the vendors suggested another solution, IBM Planning Analytics. It is a system for automatic planning, budgeting, forecasting and analysis processes. (IBM, 2018)

The system listed advantage that is used powerful IBM TM1 OLAP engine. It has an interactive workspace and it can be used to simulate alternative scenarios. The interface is similar to Microsoft excel with full excel capabilities and the deployment can be chosen from cloud, on-premises or mixed.

Figure 49 IBM Planning Analytics (IBM, 2018)

The systems has many key features. Customised workspace means that the workspace is interactive and can be deployed to different roles. Data integration enables cooperation with exciting applications. In-memory analytics provides real-time insights across your business dimensions, at the level of detail needed. Predictive insights are uncovered automatically directly from the internal or external data and lets you test business assumptions and examine alternative solutions. IBM Planning Analytics has a flexible and scalable deployment meaning that it is deployable on cloud, on premises or in mixed deployment environments for use by individuals, teams, workgroups and the entire enterprise. The tool supports multidimensional scenario modelling that helps to compare different scenarios. (IBM, 2018)

This solutions is fit for the task, but will involve some customisation. This is so called “Customer solution” meaning that interfaces, model logic and reporting are all done customized.

6.2.2 Comparison of the alternative systems

All the alternative systems are very diverse. All of the systems have very different strengths and weaknesses as a system. The strengths and weaknesses of the systems fit for Lindström are very different too.

D365 Master Planning

The strengths of D365 is of course that it is the future purchase system. This would make the integration to Lindströms' ecosystem easier and the processes easier. This way the execution of the plan could be done easily with the same system. In fact, D365 is able to create the purchase orders based on the plan. Microsoft has really worked on the user interface so that the system is as easy to use as possible. Also since the Microsoft CRM is already in use, the system is familiar to the user.

D365 weaknesses are the capacity in number of products. Also the system supports only listed suppliers per product. It cannot consider alternative supplier to different sizes of the product. Changing an order from the supplier A to supplier B can be difficult.

Figure 50 D365 Master Planning SWOT

By using the standard module of D365 there are many opportunities for wider use of D365. The co-operation between modules in this ERP system could be used. In the future it is certain that the collaboration is possible. As a large product developer, Microsoft is stable and reliable. The updates to the system are continuous. There are also many different system providers for the system in Finland so there are many options.

As the D365 project has been postponed for later, all the integrations are coming. As the purchase system is a significant part of the purchase system, the integrations are extensive. The use of the long term plan are a threat in a way that how reliable are these plans.

Quintiq Company Planner

The largest strength of Quintiq is that it is already in use in planning. Quintiq is the software used for demand forecasting and aggregate purchase planning. It already includes most of the information needed to make a mid-term plan. The system is already familiar to Lindström and there is an ongoing project open with Quintiq. The suitability for Lindström has been tested already. As the system is the same as used in long-term planning, it is possible to have feed back to the long term plan. This way there is no need to make changes twice.

The Quintiq Company Planner is planned to run daily so it could be too excessive for this process. The planning is done with much more details that are needed and takes quite much effort. Quintiq as a system does not have a system for execution, and with D365 on the way, the execution of the plan will always need to be a separate step.

Figure 51 Quintiq Company Planner SWOT

The opportunities for this system are that there is an opportunity for daily planning. This way the same system as used for mid-term planning weekly, could be broadened to daily planning with order promising functions.

The major external threats are the price of the system. Quintiq is a very comprehensive system and the price matches that.

Rob-ex

Rob-ex is a system that is used for production planning in Prodem. It is an APS system that is main function is to schedule. It already has all the functions that are needed for mid-term planning. Because Prodem, Lindströms' own factory uses this system and they are happy with it, it is safe to say that it works. Because Prodem only considers scheduling its own production with its own fabrics, it would need a separate integration to include all suppliers' information.

Because it is only used in Prodem it is not familiar to the Supply Planner and many other people. Rob-ex is also planned for shop floor daily planning, but there has been use cases for planning in intermediate level.

Figure 52 Rob-ex SWOT

The main opportunity of Rob-ex is that it is already used in Lindström and will be used in future factories as well. This way the integration to shop floor could operate seamlessly.

The biggest thread is that the system is not made for mid-term planning. It is not a clear fit to the problem.

IBM Planning Analysis

IBM Planning Analysis tool is a system that is customised to fit the solution. This as expected makes it do what is wanted. This is the biggest strength because it will be a perfect fit. It has a visual side that can be used to analyse the situation and compare different solutions. This visual side of the system also helps to share the information.

The weaknesses are that as a new system that is not already in either end of the planning process, the integrations need to be started from the beginning. The IBM tool is a very effective tool that needs a lot of capacity to function.

Figure 53 IBM Planning Analysis SWOT

As the system is made for the problem, the opportunities before design parameters are unlimited. The system could be used for any type of planning wanted. It is also capable for effective analysis with IMB Watson. This solution could be spread wider in Lindström to cover all sorts of planning, analysis and reporting.

As it is a new system, there are risks. There are no guarantees how the system will work in Lindström infrastructure. Because the system is built separately to each customer, it means customisation. This also means that each function needs to be designed in collaboration with Lindström and the service provider. This needs a lot of resources and understanding in Lindströms' side of the deal.

7 Conclusions

This thesis is about the needs assessment for a mid-term capacity planning process and tool. There is definitely a need for this piece in the supply planning for Lindström. For now there is no process that validates the long term plan or executes it. Therefore, the long term plan is a detached proposal that is not implemented to its full potential.

This mid-term plan will combine the planned capacity and used supplier capacity. The planned capacity is detailed and reacts to changing situations of the customer projects. This process could also be used for execution of the long term plan. As the long term plan gives the supply plan for a supplier per products for a month, the mid-term plan could still make changes. This could mean that the changes to the selected supplier for a product needs to be made monthly and weekly. It would be easier to trust the mid-term plan to consider the monthly plan as a base and only make changes to the supplier based on that.

The process for the mid-term planning has been accepted and hopefully will be implemented as a tool in use. The important parts of the process are following the capacity usage, so that the possible overflows can be reacted to. By following the historical usage, the problems can be reacted to or moved to other suppliers in the future. By arrangement the projects Lindström gets the schedules for customer projects and as available to promise the delivery dates to the customer. The important part of the process, and the most complicated one, is sharing the plan. By effectively sharing it, the plan goes to execution. There are many different stakeholders who rely on the plan and whose work is affected by it.

All the software compared in this thesis were very different. D365 Master planning is a suitable system that is part of the upcoming purchase system. But there are some complications on the way, such as the schedule of the upcoming D365 project. Quintiq Company Planner is an effective planning tool that is a separate module of the system already used for long term planning. The system is made so that it could even be used for daily planning. Rob-ex is a very good scheduling system but there are no guarantees it will work in higher level of planning. The IMB system is the most flexible one but will require a lot of effort from Lindströms side.

If there were no rush to get the planning tool ready as soon as possible, the D365 Master Planning module would be the most suitable option. Because of the big integration and changes in processes with the new purchasing system the project would take a substantially time. Of course all this work would be away from the upcoming IT project. There is the option still that the optimal solution for the tool is a system that was not evaluated in this study. There are many different systems available and if the restriction of the software being already in use for Lindström is taken away, there might be better suited systems available that are suited for the task.

There is no schedule for the continuation of this project. The plan is to get the implementation before the change of the purchasing system as shown in the process chart. It should be fully functional before 2020. The CRM development project is also not scheduled yet with no knowledge of the estimated finish date or progress. Even though the full scale advantage of the project cannot be obtained before the CRM development project has finished parts of it could be implemented sooner. Before the CRM delivery projects are used in subsidiaries, there is no way to use the scheduling for the customer projects outside Finland. At least not

the way planned. This does not mean that the supplier capacities could not be followed, and that was the main focus all along.

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